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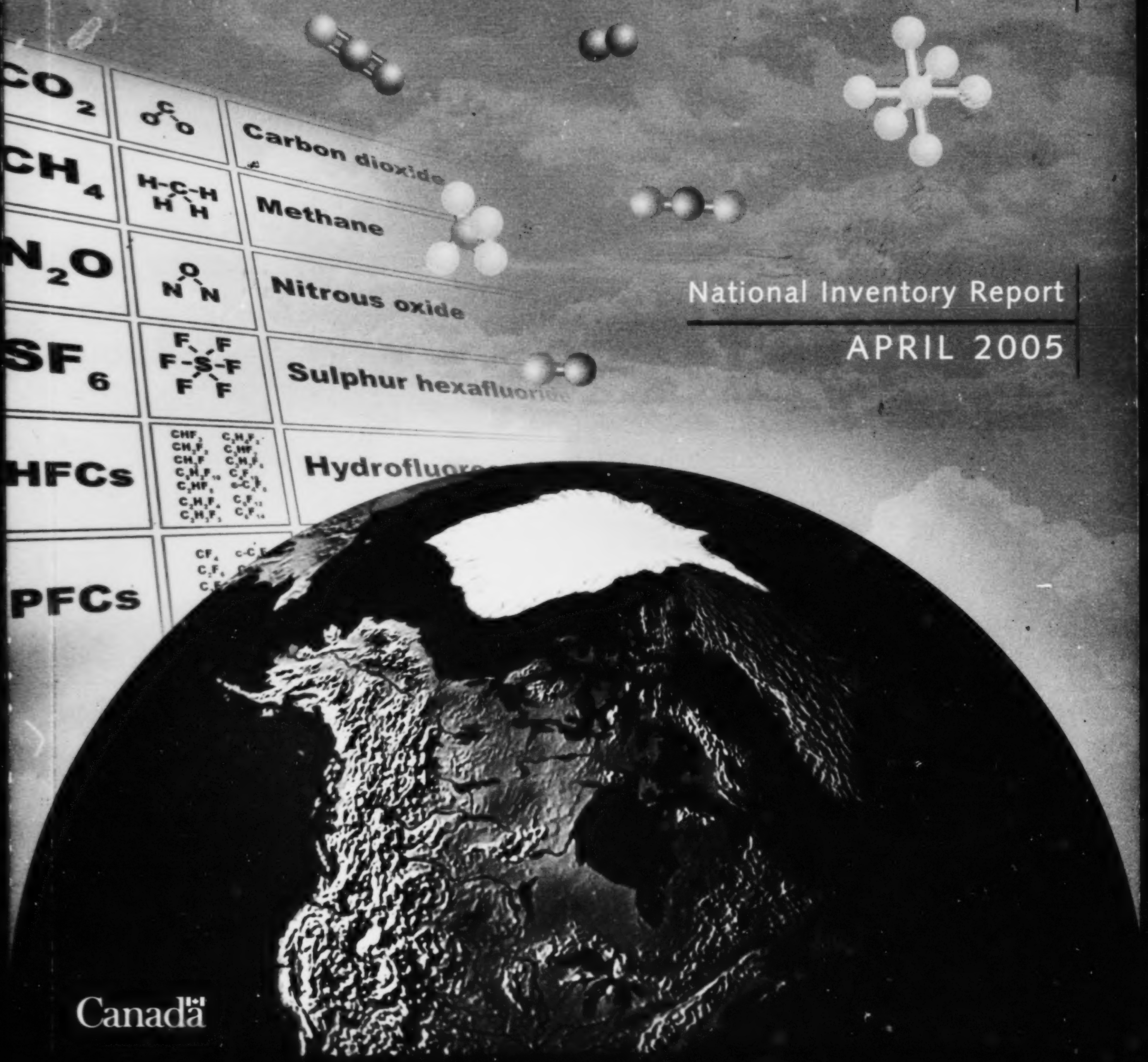
Canada's Greenhouse Gas Inventory

1990–2003



CO_2
Carbon dioxide
CH_4
H-C-H
Methane
N_2O
Nitrous oxide
SF_6
Sulphur hexafluori
HFCs
Hydrofluor
PFCs

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Canada's Greenhouse Gas Inventory

1990–2003

Greenhouse Gas Division
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APRIL 2005

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FOREWORD

On December 4, 1992, Canada ratified the United Nations Framework Convention on Climate Change (UNFCCC), which subsequently entered into force in March 1994. Articles 4 and 12 of the Convention on Climate Change state that Parties to the Convention shall submit to the Secretariat national greenhouse gas (GHG) inventories of anthropogenic emissions by sources and removals by sinks. Annex I Parties are required to submit their national GHG inventories by April 15 in accordance with Decision 18/CP.8, in the form of a National Inventory Report and the Common Reporting Format.

The UNFCCC Reporting Guidelines on Annual Inventories,[1] agreed to at the Eighth and Ninth Conferences of the Parties, incorporate the methodological guidance that has been developed by the Intergovernmental Panel on Climate Change.[2] These guidelines stipulate how emission estimates are to be prepared and what is to be included in the annual inventory report, including additional information on documentation, data acquisition processes, and structures that Parties have in place to produce accurate and reliable GHG inventories. In addition, by including additional information, the inventory report serves as a much better tool from which to generate indicators to compare Parties' performance under the UNFCCC and can be seen as a necessary, but interim, step to a reporting system under the Kyoto Protocol. The Convention and the Protocol also commit Parties to improve the quality of national and regional emission data and to provide support to developing countries.

Environment Canada, in consultation with a range of stakeholders, is responsible for preparing Canada's official national inventory. This National Inventory Report, prepared by staff of the Greenhouse Gas Division of Environment Canada, complies with the UNFCCC Reporting Guidelines on Annual Inventories. It represents the efforts of many years of work and builds upon the results of previous reports, published in 1992, 1994, 1996, 1997, and yearly from 1999 to 2004. In addition to the inventory data, the inventory report contains relevant supplementary information and an analysis of recent trends in emissions and removals.

Among a number of initiatives that form part of Canada's response to climate change, emission allocation mechanisms are being examined to link, verify, and attribute domestic emission reductions to this national emissions and removals inventory to improve Canada's ability to monitor, report, and verify our GHG emissions. On March 15, 2004, the Government of Canada, in partnership with the provincial and territorial governments, launched the first phase of a mandatory GHG reporting system. By June 2005, facilities that have emissions greater than 100 kilotonnes of carbon dioxide equivalent in 2004 must report on these emissions. Data collected through this reporting system will help to add precision and detail to the national inventory.

Since the publication of the 1990 emissions inventory,[3] an ever-increasing number of people have become interested in climate change and, more specifically, GHG emissions. While this interest has sparked a number of research activities, only a limited number have focused on measuring emissions and developing better emission estimates. While there will always be uncertainties associated with emission inventories, ongoing work, both in Canada and elsewhere, will continue to improve the estimates and reduce uncertainties associated with them. Priority areas for improvement include both the quality of input data and the methodologies utilized to develop emission and removal estimates. A number of areas have undergone improvements over the last few years as we improve the quality of the inventory. These improvements are described within the report.

Art Jaques, P. Eng.
April 15, 2005

Chief, Greenhouse Gas Division
Environment Canada

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[1] FCCC/CP/2002/8.

[2] Referred to as the IPCC Good Practice Guidance.

[3] Jaques, A.P. (1992), *Canada's Greenhouse Gas Emissions: Estimates for 1990*, Environmental Protection, Conservation and Protection, Environment Canada, EPS 5/AP/4, December.

LIST OF ACRONYMS, ABBREVIATIONS, AND UNITS

AAC	Aluminium Association of Canada
AC	air conditioning
AC OEM	air conditioning original equipment manufacture
Al	aluminium
Al_2O_3	alumina
ASH	manure ash content
AWMS	animal waste management system
B_0	maximum methane production potential
BCEF	biomass conversion/expansion factor
C	carbon
CAC	Criteria Air Contaminant
$CaCO_3$	calcium carbonate
$CaMg(CO_3)_2$	dolomite
CanFI	Canada Forest Inventory
CanSIS	Canadian Soil Information System
CaO	lime
CAPP	Canadian Association of Petroleum Producers
CBM	Carbon Budget Model
CBM-CFS	Carbon Budget Model of the Canadian Forest Sector
CCFM	Canadian Council of Forest Ministers
CCS	Census Consolidated Subdivision
CEA	Canadian Electricity Association
CEPA 1999	*Canadian Environmental Protection Act, 1999*
CF_4	carbon tetrafluoride
C_2F_6	carbon hexafluoride
CFC	chlorofluorocarbon
CH_4	methane
CIEEDAC	Canadian Industrial Energy End-Use Data Analysis Centre
CKD	cement kiln dust
CO	carbon monoxide
CO_2	carbon dioxide
CPPI	Canadian Petroleum Products Institute
CRF	Common Reporting Format
CVS	Canadian Vehicle Survey
DE	digestible energy
DHI	Dairy Herd Improvement
DMI	dry matter intake
EAF	electric arc furnace
ECR	Environmental Commitment and Responsibilities
EF	emission factor
EPA	Environmental Protection Agency (United States)
EPWG	Emissions and Projections Working Group
eq	equivalent
ERT	Expert Review Team
FCR	fuel consumption ratio
FEMS	Farm Environmental Management Survey
g	gram
GDP	gross domestic product
GE	gross energy
Gg	gigagram
GHG	greenhouse gas
GHV	gross heating value
GIS	geographic information system
GL	gigalitre
Gt	gigatonne
GWP	global warming potential
ha	hectare
HCFC	hydrochlorofluorocarbon
HDD	heating degree-day
HDDT	heavy-duty diesel truck
HDDV	heavy-duty diesel vehicle
HDGV	heavy-duty gasoline vehicle
HFC	hydrofluorocarbon
HM	heavy metal
HNO_3	nitric acid
HWP	harvested wood product
HWP-C	carbon stored in harvested wood products
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
kha	kilohectare
kPa	kilopascal
kt	kilotonne
kWh	kilowatt-hour
L	litre
lb.	pound
LDDT	light-duty diesel truck
LDDV	light-duty diesel vehicle
LDGT	light-duty gasoline truck
LDGV	light-duty gasoline vehicle
LDV	light-duty vehicle
LPG	liquefied petroleum gas
LTO	landing and takeoff
LUCF	Land-Use Change and Forestry
LULUCF	Land Use, Land-Use Change and Forestry
m	metre
m^3	cubic metre
MAI	mean annual increment
MARS	Monitoring, Accounting and Reporting System
MC	motorcycle
MCF	methane conversion factor
$MgCO_3$	dolomite
MGEM 05	Mobile Greenhouse Gas Emission Model
MgO	dolomitic lime

Mha	megahectare
mol	mole
MS	manure system distribution factor
MSW	municipal solid waste
Mt	megatonne
mV	millivolt
MW	megawatt
N	nitrogen
N_2	nitrogen gas
Na_2CO_3	sodium carbonate
Na_3AlF_6	cryolite
NAICS	North American Industrial Classification System
NFI	National Forest Inventory
NGL	natural gas liquid
NH_3	ammonia
NH_4^+	ammonium
NHV	net heating value
NIR	National Inventory Report
NMVOC	non-methane volatile organic compound
NO	nitric oxide
NO_3^-	nitrate
NO_x	nitrogen oxides
N_2O	nitrous oxide
NPRI	National Pollutant Release Inventory
NRCan	Natural Resources Canada
ODS	ozone-depleting substance
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacturer
PFC	perfluorocarbon
PJ	petajoule
POP	persistent organic pollutant
ppb	part per billion
ppbv	part per billion by volume
ppm	part per million
QA	quality assurance
QC	quality control
RESD	*Report on Energy Supply–Demand in Canada*
SF_6	sulphur hexafluoride
SIC	Standard Industrial Classification
SLC	Soil Landscapes of Canada
SO_2	sulphur dioxide
SO_x	sulphur oxides
SOC	soil organic carbon
STP	standard temperature and pressure
SUV	sport utility vehicle
t	tonne
t-km	tonne-kilometre
TJ	terajoule
TWh	terrawatt-hour
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
VIO	vehicle in operation
Vkmt	vehicle kilometres travelled
VOC	volatile organic compound
VS	volatile solids

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EXECUTIVE SUMMARY

ES.1 GREENHOUSE GAS INVENTORIES AND CLIMATE CHANGE

The United Nations Framework Convention on Climate Change (UNFCCC) — Article 4(1)(a), Article 12(1)(a), and Decision 3/CP.5 — requires Annex I Parties to submit an annual greenhouse gas (GHG) inventory report using UNFCCC Reporting Guidelines. The year 2005 marks the publication of Canada's eleventh National Inventory Report (NIR). It is also the first inventory since the Kyoto Protocol to the UNFCCC, which Canada ratified in 2002, came into force.[4] The Kyoto Protocol requires Canada to reduce its GHG emissions to 6% below 1990 levels over the period 2008–2012 (the first commitment period). Under the Protocol, Canada's national GHG emissions inventory is the tool for measuring progress against this obligation.

The entry into force of the Protocol will have implications on reporting and review requirements. Annex I countries must have in place, no later than 2007, national systems for estimating GHG emissions by sources and removals by sinks using agreed upon methodologies as outlined in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/OECD/IEA, 1997), *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000), and *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003). As a result, the UNFCCC now requires Canada to move towards more rigorous and transparent reporting of its GHG emissions, calculation methodologies, and verification procedures for the inventory. This year's GHG inventory incorporates a number of improvements in the estimation methodologies, as well as new Tier 1 annual quality assurance/quality control (QA/QC) procedures, which more formally ensure and document the quality of the estimates. In addition, in accordance with Good Practice, a new study commissioned to perform a quantitative Tier 2 evaluation of the uncertainty in the emission estimates is reported in an annex and throughout the body of this document. Finally, with this inventory, Canada commences the implementation of a new reporting format for the Land Use, Land-Use Change and Forestry (LULUCF) Sector.[5]

This year's NIR represents a significant step towards meeting the new reporting requirements under the UNFCCC, while recognizing that additional reporting elements will need to be incorporated as the first commitment period is approached.

The current report includes an inventory of anthropogenic (human-induced) emissions by sources, and removals by sinks, of all GHGs not controlled by the Montreal Protocol. This Executive Summary discusses underlying trends in these emissions, provides some international context, and presents provincial and territorial emissions for the period 1990–2003. Chapter 1, the Introduction, provides an overview of the most recent climate and GHG concentration trends as well as Canada's institutional arrangements for producing the inventory, a brief description of estimation methodologies and QA/QC procedures, and explanations of major changes to this year's inventory and assessments of completeness and uncertainty. Chapter 2 provides an in-depth analysis of Canada's GHG emission trends in accordance with the UNFCCC Reporting Guidelines. Chapters 3–8 provide descriptions and additional analysis for each broad emissions and removals category according to UNFCCC Common Reporting Format (CRF) requirements. Chapter 9 presents a summary of recalculations and planned improvements. Annexes 1 to 7 provide a key category analysis, detailed explanations of estimation methodologies, comparisons with the reference approach, a description of recently developed QA/QC procedures, completeness assessments, and a discussion of inventory uncertainty. Summary tables of GHG emissions tabulated by jurisdiction, sector, and gas are presented in Annexes 8 and 12. Annexes 9, 10, and 11 present additional details on the GHG intensity of electricity generation and trend analyses by industrial sector and by province/territory, respectively. Emission factors are provided in Annex 13. Annex 14 discusses the rounding protocol developed for the estimates presented in the NIR. Finally, Annex 15 presents tables for indirect GHG's SO_x, NO_x, CO and NMVOCs.

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[4] The Kyoto Protocol entered into force on February 16, 2005, 90 days after the Russian Federation, an "Annex 1" Party, deposited its instrument of ratification. This fulfilled the latter part of the requirement, which states that not fewer than 55 Parties to the Convention, incorporating Parties included in Annex I that accounted in total for at least 55% of the total carbon dioxide emissions for 1990 of the Parties included in Annex I, must ratify for the Protocol to come into force (see Article 25 of the Kyoto Protocol).

[5] Formerly known as the Land-Use Change and Forestry (LUCF) Sector.

ES.1.1 DEVELOPING CANADA'S NATIONAL GREENHOUSE GAS INVENTORY

On behalf of the Government of Canada, Environment Canada develops and publishes annually Canada's GHG Inventory. The GHGs for which emissions and removals have been estimated in the national inventory are:

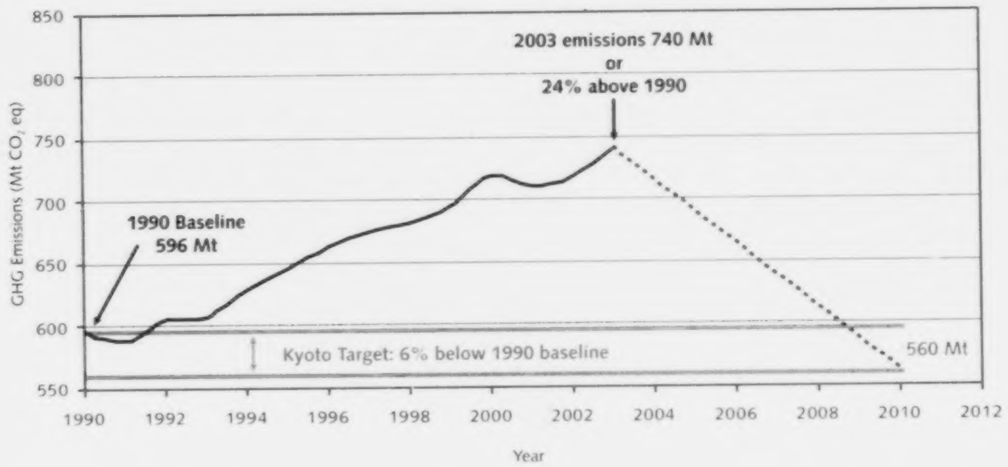
- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- sulphur hexafluoride (SF_6);
- perfluorocarbons (PFCs); and
- hydrofluorocarbons (HFCs).

The inventory reporting format is based on international reporting methods agreed to by the Parties to the UNFCCC and according to the procedures of the Intergovernmental Panel on Climate Change (IPCC) (see above). The inventory uses an internationally agreed upon reporting format that groups emissions into the following six sectors: Energy, Industrial Processes, Solvent and Other Product Use, Agriculture, LULUCF, and Waste. Each of these sectors is further subdivided within the inventory and follows, as closely as possible, the UNFCCC category and subsector divisions.[6] Detailed descriptions of the methodologies used to estimate the sector emissions and removals and their respective trends are provided in Chapters 3 through 8 and Annexes 2 and 3.

ES.2 SUMMARY OF NATIONAL TRENDS IN GREENHOUSE GAS EMISSIONS AND REMOVALS

In 2003, Canadians contributed about 740 megatonnes of CO_2 equivalent (Mt CO_2 eq[7]) of GHGs to the atmosphere (Figure S-1),[8] an increase of 3.0% over the

FIGURE S-1: Canadian Emission Trend and Kyoto Target



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[6] Minor differences exist between the UNFCCC and Canada's national inventory sector designations. These are explained in footnotes throughout this report. More details can be found in Chapters 3–8 where the methodology used in Canada's inventory is described.

[7] Each of the GHGs has a unique average atmospheric lifetime over which it is an effective climate-forcing agent. The concept of global warming potential (GWP) has been introduced to equate this climate forcing for different GHGs to that of CO_2. A more detailed explanation is provided in Section 1.1.5 of this document.

[8] Unless explicitly stated otherwise, all emission estimates given in Mt represent emissions of GHGs in Mt CO_2 equivalent.

719 Mt recorded in the year 2002. This is considerably greater than the 1.0% increase that occurred between 2001 and 2002. Canada's economic GHG intensity — the amount of GHGs emitted per unit of economic activity — was 1.2% higher in 2003 than in 2002. Since 1990, emissions have increased by about 24%.

Table S-1 depicts Canada's total GHG emissions from 1990 to 2003, along with several primary indicators: gross domestic product (GDP), population, energy use, energy production, and energy export. From the table, it is evident that the 24% increase in GHG emissions during the 13-year period outpaced increases in population (which totalled 14%) and approximately equalled the increase in energy use (which was 23%). However, the growth in total emissions was well short of the 43% growth in GDP between 1990 and 2003 (Statistics Canada, #13-213: millions of chained 1997 dollars).

The result is that economic GHG intensity has decreased by a total of 13% over the period, an average of 1.0% per year. More goods were manufactured, more commercial activity occurred, and more travel took place per unit of GHG emissions. These trends are summarized graphically in Figure S-2. The indexed curves clearly show that GHG per energy use remained static over the period, while economic GHG intensity decreased. This is the result of energy efficiency improvements that took place in the Canadian economy since 1990 (NRCan, 2004).

Another trend worth noting is the much larger growth in energy *production* than energy *use* between 1990 and 2003. This is a consequence of sharp increases in energy exports over the period, which have had a significant impact on the emission trend. (See Section ES.4.1 for more details.)

TABLE S-1: Canada's GHG Emissions and Accompanying Variables, 1990–2003

	1990	1995	2000	2001	2002	2003
Total GHG Emissions (Mt)[1]	**596**	**646**	**720**	**712**	**719**	**740**
Growth Since 1990	N/A	8.5%	20.9%	19.5%	20.7%	24.2%
Annual Change	N/A	2.7%	3.5%	-1.1%	1.0%	3.0%
Average Annual Change	N/A	1.7%	2.1%	1.8%	1.7%	1.9%
GDP → Expense[2]	**765 311**	**833 456**	**1 020 786**	**1 040 388**	**1 074 516**	**1 092 891**
Growth Since 1990	N/A	8.9%	33.4%	35.9%	40.4%	42.8%
Annual Change	N/A	2.8%	5.3%	1.9%	3.3%	1.7%
Average Annual Change	N/A	1.8%	3.3%	3.3%	3.4%	3.3%
Economic GHG Intensity (Mt/$B GDP)	**0.78**	**0.78**	**0.71**	**0.68**	**0.669**	**0.677**
Growth Since 1990	N/A	-0.4%	-9.4%	-12.1%	-14.1%	-13.0%
Annual Change	N/A	-0.1%	-1.7%	-3.0%	-2.2%	1.2%
Average Annual Change	N/A	-0.1%	-0.9%	-1.1%	-1.2%	-1.0%
GHG Efficiency ($GDP/kt GHG)	**1.28**	**1.29**	**1.42**	**1.46**	**1.495**	**1.476**
Growth Since 1990	N/A	0.4%	10.4%	13.8%	16.4%	15.0%
Annual Change	N/A	0.1%	1.7%	3.1%	2.3%	-1.2%
Average Annual Change	N/A	0.1%	1.0%	1.3%	1.4%	1.2%
Population (000s)[3]	**27 698**	**29 302**	**30 689**	**31 021**	**31 362**	**31 630**
Growth Since 1990	N/A	5.8%	10.8%	12.0%	13.2%	14.2%
Annual Change	N/A	1.0%	0.9%	1.1%	1.1%	0.9%
Average Annual Change	N/A	1.2%	1.1%	1.1%	1.1%	1.1%
GHG per Capita (t/person)	**21.5**	**22.1**	**23.5**	**23.0**	**22.92**	**23.4**
Growth Since 1990	N/A	2.5%	9.1%	6.7%	6.6%	8.8%
Annual Change	N/A	1.6%	2.6%	-2.2%	-0.1%	2.1%
Average Annual Change	N/A	0.5%	0.9%	0.6%	0.5%	0.7%
Energy Use (PJ)[4]	**9 230**	**9 695**	**10 830**	**10 950**	**11 076**	**11 363**
Growth Since 1990	N/A	5.0%	17.3%	18.6%	20.0%	23.1%
Annual Change	N/A	1.4%	3.0%	1.1%	1.2%	2.6%
Average Annual Change	N/A	1.0%	1.7%	1.7%	1.7%	1.8%
Energy Produced (PJ)[5]	**7 746**	**10 299**	**11 729**	**11 949**	**12 336**	**12 452**
Growth Since 1990	N/A	33.0%	51.4%	54.3%	59.3%	60.7%
Annual Change	N/A	4.6%	3.8%	1.9%	3.2%	0.9%
Average Annual Change	N/A	6.6%	5.1%	4.9%	4.9%	4.7%
Net Energy Exported (PJ)[5]	**1 769**	**4 056**	**4 851**	**4 989**	**5 294**	**4 958**
Growth Since 1990	N/A	129.2%	174.2%	182.0%	199.2%	180.2%
Annual Change	N/A	14.8%	6.1%	2.8%	6.1%	-6.3%
Average Annual Change	N/A	25.8%	17.4%	16.5%	16.6%	13.9%
Emissions Associated with Net Exports (Mt)[5]	**21.5**	**42.9**	**47.5**	**47.6**	**51.1**	**46.2**
Growth Since 1990	N/A	99.5%	121.0%	121.5%	137.8%	115.1%
Annual Change	N/A	17.9%	4.7%	0.2%	7.3%	-9.6%
Average Annual Change	N/A	19.9%	12.1%	11.0%	11.5%	8.9%

1 This report

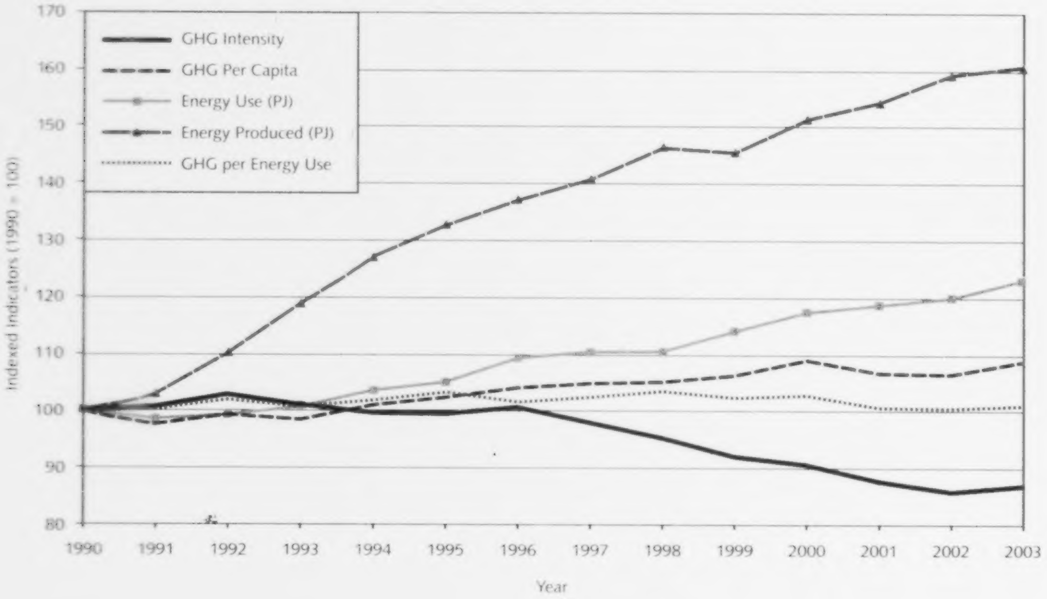
2 Gross domestic product (GDP), expenditure-based (million 1997 chained dollars). Source: Statistics Canada, *Provincial Economic Accounts, Annual Estimates, 2003*, #13-213 PPB, Table 3, Line 21 - 2003

3 Source: Statistics Canada, *Demographic Statistics 2003*, #91-213-XPB

4 Statistics Canada, *Report on Energy Supply–Demand in Canada 2003*, #57-003-XIB, Table 5, Line 2 - Availability, Total Primary

5 Natural gas and crude oil only. "Net Exports" refers to exports minus imports. Source: See Section ES 4.1

FIGURE S-2: Trends in GHG Emissions per Capita and per Unit GDP, 1990–2003



ES.3 EMISSIONS AND REMOVALS ESTIMATES AND TRENDS

ES.3.1 2003 EMISSIONS AND REMOVALS

Table S-2 details Canada's emissions and removals for 2003. On an individual GHG basis, CO_2 contributed 79% of the total emissions, while CH_4 accounted for 13%. N_2O accounted for 7% of the emissions, while PFCs, SF_6, and HFCs constituted the remaining 1%.

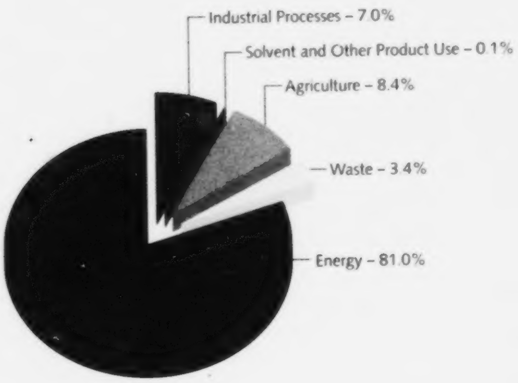
Approximately 74% of total GHG emissions in 2003 resulted from the combustion of fossil fuels. Another 7% were from fugitive sources, with the result that over 81% of emissions were from the Energy Sector. A sectoral breakdown of Canada's total emissions for 2003 is shown in Figure S-3.

Changes from the Previous National Inventory Report

Canada's 1990–2002 GHG estimates have been revised since last year's inventory report. Due to changes in the Reporting Guidelines, CO_2 emissions from agricultural soils and non-CO_2 emissions from forest fires are now reported within the LULUCF Sector (previously known as Land-Use Change and Forestry, or LUCF). Since the national inventory totals exclude the GHG emissions and removals from the LULUCF Sector, these categories, previously included in the national totals, are now excluded. In addition, estimates for emissions from the aluminium production industry, which appear under Industrial Processes – Metal Production, have been revised, as well as the method of allocating emissions between domestic and international aviation. Taken together, these changes (described in greater detail in the body of this document) are the primary contributors to the revised national GHG estimates.

As a result, total GHG emissions previously reported for 1990 have been revised downward from 609 Mt to 596 Mt, while emission estimates previously reported for 2002 have been revised downward from 731 Mt to 719 Mt. The overall impact of these changes is that emission growth over the period 1990–2002, previously reported to be about 20%, is now estimated to be approximately 21%.

FIGURE S-3: Sectoral Breakdown of Canada's GHG Emissions, 2003



As per new reporting requirements, neither the net CO_2 flux nor the non-CO_2 forest fire emissions associated with the LULUCF Sector are included in the inventory totals. CO_2 fluxes from agricultural soils are also excluded from national totals and are part of the LULUCF Sector. Total emissions for the LULUCF Sector are estimated at 25 Mt, while removals total -69 Mt, for net overall removals of -44 Mt in 2003.

ES.3.2 SECTOR TRENDS

ES.3.2.1 Year-to-Year Changes

Table S-3 outlines changes in Canada's GHG emissions and removals, by sector, between 1990 and 2003. As indicated above, emissions in 2003 are estimated at 740 Mt, up 21 Mt (3%) from 2002's value of 719 Mt. Among the largest contributors to the year-to-year increase were the Electricity and Heat Generation, Commercial & Institutional, and Residential categories, all within the Energy Sector.

Due to low water levels in major lakes, rivers, and reservoirs in 2003, hydroelectric generation was reduced, resulting in greater reliance on fossil fuel-fired generation and a 5 Mt increase in emissions from electricity production.

Canadian homes and businesses required, on average, more energy for space heating in the winter of 2003 than in the winter of 2002, due to colder temperatures. In 2003, the Canada-wide number of Heating Degree Days (HDDs), an indicator of the necessity for space heating due to the severity of cold weather, was up 5.2% compared with 2002. This had a large impact on fossil fuel consumption in the Commercial & Institutional and Residential subsectors, where emissions rose by a sum of almost 5.5 Mt from 2002.

Mining, up by 4 Mt as a result of increased activity within the subsector, also contributed significantly to 2002–2003 growth, as did the Agriculture Sector, to a lesser extent. N_2O emissions from Agricultural Soils increased by 2.6 Mt in 2003, mainly due to higher crop production that year.

Between 2002 and 2003, Heavy-Duty Diesel Vehicles (HDDVs, large transport trucks) and Light-Duty Gasoline Trucks (LDGTs, including pickup trucks, sport utility vehicles [SUVs], and some vans) showed emission increases of 2.5 Mt and 1.2 Mt, respectively. This growth is a continuation of long-term trends in road transport.

The oil and gas industry, including Fossil Fuel Industries, Oil and Natural Gas fugitives, and Pipelines, reduced its emissions by 4 Mt in 2003. This is of particular note, as the oil and gas subsector has, over the longer term, been a very significant source of emission growth.

TABLE S-2: Canada's GHG Emissions by Gas and Sector, 2003

	Greenhouse Gases								
GHG Source/Sink Categories	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**586 000**	**4 500**	**94 000**	**160**	**50 000**	**3 100**	**2 760**	**4 100**	**740 000**
ENERGY	**546 000**	**2 000**	**40 000**	**30**	**10 000**	–	–	–	**600 000**
a. Stationary Combustion Sources	**351 000**	**200**	**5 000**	**9**	**3 000**	–	–	–	**358 000**
Electricity and Heat Generation	133 000	5.0	110	2	800	–	–	–	134 000
Fossil Fuel Industries	69 000	100	2 000	2	500	–	–	–	71 000
Petroleum Refining	34 000	0.5	10	0.5	100	–	–	–	34 000
Fossil Fuel Production	34 800	100	2 000	1	300	–	–	–	38 000
Mining	15 600	0.3	7	0.3	100	–	–	–	15 700
Manufacturing Industries	48 600	3	60	2	500	–	–	–	49 200
Iron and Steel	6 360	0.2	5	0.2	60	–	–	–	6 420
Non-Ferrous Metals	3 190	0.07	1	0.05	20	–	–	–	3 200
Chemical	5 700	0.12	2.5	0.1	30	–	–	–	5 740
Pulp and Paper	8 820	2	40	0.9	300	–	–	–	9 130
Cement	4 180	0.08	2	0.05	10	–	–	–	4 200
Other Manufacturing	20 400	0.4	9	0.4	100	–	–	–	20 500
Construction	1 290	0.02	0.5	0.03	9	–	–	–	1 300
Commercial & Institutional	38 800	0.7	10	0.8	200	–	–	–	39 000
Residential	42 800	90	2 000	2	500	–	–	–	45 000
Agriculture & Forestry	2 200	0.04	0.8	0.06	20	–	–	–	2 210
b. Transportation	**179 000**	**30**	**600**	**30**	**8 000**	–	–	–	**190 000**
Domestic Aviation	7 000	0.4	9	0.7	200	–	–	–	7 200
Road Transportation	135 000	12	260	17	5 100	–	–	–	140 000
Light-Duty Gasoline Vehicles	47 300	3.7	78	6.3	1 900	–	–	–	49 300
Light-Duty Gasoline Trucks	39 200	4.5	94	8.4	2 600	–	–	–	41 900
Heavy-Duty Gasoline Vehicles	3 950	0.55	12.0	0.59	180				4 140
Motorcycles	221	0.18	3.7	0.00	1.3	–	–	–	226
Light-Duty Diesel Vehicles	706	0.02	0.4	0.05	20	–	–	–	723
Light-Duty Diesel Trucks	775	0.02	0.4	0.06	20	–	–	–	793
Heavy-Duty Diesel Vehicles	41 600	2	40	1	400				42 000
Propane & Natural Gas Vehicles	780	.1	30	0.02	5	–	–	–	810
Railways	5 260	0.3	6	2	700	–	–	–	6 000
Domestic Marine	5 830	0.5	10	1	300	–	–	–	6 100
Others	26 000	10	300	6	2 000	–	–	–	30 000
Off-Road Gasoline	4 000	5	100	0.09	30	–	–	–	4 000
Off-Road Diesel	13 000	0.7	10	5	2 000				20 000
Pipelines	8 850	8.8	190	0.2	70	–	–	–	9 110
c. Fugitive Sources	**15 000**	**1 800**	**39 000**	–	–	–	–	–	**54 000**
Coal Mining	–	50	1 000	–	–	–	–	–	1 000
Oil and Natural Gas	15 000	1 800	38 000	–	–	–	–	–	53 000
Oil	47.1	630	13 000	–	–	–	–	–	13 000
Natural Gas	29	1 100	24 000	–	–	–	–	–	24 000
Venting	7 800	–	–	–	–	–	–	–	7 800
Flaring	7 380	31.2	654	–	–	–	–	–	8 000
INDUSTRIAL PROCESSES	**40 200**	–	–	**6.1**	**1 890**	**3 100**	**2 760**	**4 070**	**52 000**
a. Mineral Production	**8 700**	–	–	–	–	–	–	–	**8 700**
Cement	6 800	–	–	–	–	–	–	–	6 800
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	230	–	–	–	–	–	–	–	230
b. Chemical Industry	**6 200**	–	–	**6.1**	**1 890**	–	–	–	**8 100**
Ammonia Production	6 200	–	–	–	–	–	–	–	6 200
Nitric Acid Production	–	–	–	2.6	810	–	–	–	810
Adipic Acid Production	–	–	–	3.5	1 090	–	–	–	1 090
c. Metal Production	**12 000**	–	–	–	–	–	**2 740**	**2 480**	**16 800**
Iron and Steel Production	7 040	–	–	–	–	–	–	–	7 040
Aluminium Production	4 600	–	–	–	–	–	2 740	–	7 320
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	2 480	2 480
d. Consumption of Halocarbons and SF_6	–	–	–	–	–	**3 100**	**19**	**1 600**	**4 700**
e. Other & Undifferentiated Production	**14 000**	–	–	–	–	–	–	–	**14 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	**1.5**	**480**	–	–	–	**480**
AGRICULTURE	–	**1 240**	**26 100**	**120**	**36 000**	–	–	–	**62 000**
a. Enteric Fermentation	–	**1 070**	**22 400**	–	–	–	–	–	**22 400**
b. Manure Management	–	**170**	**3 700**	**13**	**4 100**	–	–	–	**7 800**
c. Agricultural Soils	–	–	–	**100**	**32 000**	–	–	–	**32 000**
Direct Sources	–	–	–	82	25 000	–	–	–	25 000
Indirect Sources	–	–	–	20	7 000	–	–	–	7 000
WASTE	**290**	**1 100**	**24 000**	**3**	**1 000**	–	–	–	**25 000**
a. Solid Waste Disposal on Land	–	**1 100**	**24 000**	–	–	–	–	–	**24 000**
b. Wastewater Handling	–	**19**	**410**	**3**	**1 000**	–	–	–	**1 400**
c. Waste Incineration	**290**	**0.3**	**7**	**0.2**	**60**	–	–	–	**360**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-46 000**	**43**	**900**	**3.2**	**1 000**	–	–	–	**-44 000**
a. Forest Land	**-71 000**	**43**	**900**	**3.2**	**1 000**	–	–	–	**-69 000**
b. Cropland[2]	**14 000**	–	–	–	–	–	–	–	**14 000**
c. Grassland	**5 000**	–	–	–	–	–	–	–	**5 000**
d. Wetlands	–	–	–	–	–	–	–	–	–
e. Settlements	**6 000**	–	–	–	–	–	–	–	**6 000**

Notes:

1 National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

2 CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Totals may not add due to rounding.

TABLE S-3: Canada's GHG Emission Trends by Sector, 1990–2003

GHG Source/Sink Categories	1990	1995	2000	2002	2003
			kt CO_2 eq		
TOTAL	596 000	646 000	720 000	719 000	740 000
ENERGY	**469 000**	**508 000**	**582 000**	**583 000**	**600 000**
a. Stationary Combustion Sources	**282 000**	**295 000**	**345 000**	**346 000**	**358 000**
Electricity and Heat Generation	95 300	101 000	132 000	129 000	134 000
Fossil Fuel Industries	52 000	55 000	67 000	73 000	71 000
Petroleum Refining	26 000	28 000	28 000	34 000	34 000
Fossil Fuel Production	25 000	26 000	39 000	39 000	38 000
Mining	6 200	7 860	10 400	11 800	15 700
Manufacturing Industries	54 900	53 100	53 200	49 100	49 200
Iron and Steel	6 490	7 040	7 190	6 490	6 420
Non-Ferrous Metals	3 230	3 110	3 190	3 220	3 200
Chemical	7 100	8 460	7 860	6 130	5 740
Pulp and Paper	13 600	11 700	11 000	9 210	9 130
Cement	3 590	3 420	3 970	4 180	4 200
Other Manufacturing	20 900	19 400	20 000	19 900	20 500
Construction	1 880	1 180	1 080	1 240	1 300
Commercial & Institutional	25 800	29 000	33 200	35 400	39 000
Residential	44 000	45 000	45 000	44 000	45 000
Agriculture & Forestry	2 420	2 790	2 570	2 100	2 210
b. Transportation	**150 000**	**160 000**	**180 000**	**180 000**	**190 000**
Domestic Aviation	6 400	5 900	6 600	6 800	7 200
Road Transportation	107 000	119 000	131 000	137 000	140 000
Light-Duty Gasoline Vehicles	53 800	51 400	48 200	49 700	49 300
Light-Duty Gasoline Trucks	21 700	28 400	37 600	40 700	41 900
Heavy-Duty Gasoline Vehicles	3 140	4 760	4 370	4 140	4 140
Motorcycles	230	214	238	227	226
Light-Duty Diesel Vehicles	672	594	604	683	723
Light-Duty Diesel Trucks	591	417	645	755	793
Heavy-Duty Diesel Vehicles	24 500	30 800	38 700	39 600	42 000
Propane & Natural Gas Vehicles	2 200	2 100	1 100	850	810
Railways	7 000	6 000	7 000	6 000	6 000
Domestic Marine	5 000	4 400	5 100	5 500	6 100
Others	20 000	30 000	30 000	30 000	30 000
Off-Road Gasoline	5 000	4 000	6 000	4 000	4 000
Off-Road Diesel	10 000	10 000	20 000	10 000	20 000
Pipelines	6 900	12 000	11 300	10 900	9 110
c. Fugitive Sources	**37 900**	**49 800**	**54 000**	**54 500**	**54 000**
Coal Mining	2 000	2 000	900	1 000	1 000
Oil and Natural Gas	36 000	48 100	53 000	53 500	53 000
Oil	8 600	13 000	14 000	13 000	13 000
Natural Gas	17 000	22 000	24 000	24 000	24 000
Venting	4 500	6 700	7 500	8 100	7 800
Flaring	5 800	6 800	7 800	8 000	8 000
INDUSTRIAL PROCESSES	**54 400**	**57 300**	**52 400**	**51 000**	**52 000**
a. Mineral Production	**7 800**	**8 100**	**9 000**	**8 600**	**8 700**
Cement	5 600	5 900	6 700	6 700	6 800
Lime	2 000	2 000	2 000	2 000	2 000
Limestone and Soda Ash Use	440	360	420	230	230
b. Chemical Industry	**17 000**	**18 000**	**8 500**	**8 300**	**8 100**
Ammonia Production	5 000	6 500	6 800	6 200	6 200
Nitric Acid Production	780	780	800	810	810
Adipic Acid Production	10 700	10 700	900	1 250	1 090
c. Metal Production	**19 100**	**19 100**	**18 400**	**17 100**	**16 800**
Iron and Steel Production	7 060	7 880	7 890	7 110	7 040
Aluminium Production	8 930	9 090	7 730	7 110	7 320
SF_6 Used in Magnesium Smelters and Casters	3 110	2 110	2 790	2 910	2 480
d. Consumption of Halocarbons and SF_6	**1 800**	**2 000**	**4 600**	**4 200**	**4 700**
e. Other & Undifferentiated Production	**9 200**	**10 000**	**12 000**	**13 000**	**14 000**
SOLVENT & OTHER PRODUCT USE	**420**	**440**	**460**	**470**	**480**
AGRICULTURE	**52 000**	**58 000**	**61 000**	**59 000**	**62 000**
a. Enteric Fermentation	**18 700**	**21 300**	**20 800**	**22 200**	**22 400**
b. Manure Management	**6 600**	**7 200**	**7 200**	**7 800**	**7 800**
c. Agricultural Soils	**27 000**	**30 000**	**33 000**	**29 000**	**32 000**
Direct Sources	22 000	24 000	26 000	23 000	25 000
Indirect Sources	5 000	6 000	7 000	6 000	7 000
WASTE	**20 000**	**22 000**	**25 000**	**25 000**	**25 000**
a. Solid Waste Disposal on Land	**19 000**	**20 000**	**23 000**	**23 000**	**24 000**
b. Wastewater Handling	**1 200**	**1 300**	**1 400**	**1 400**	**1 400**
c. Waste Incineration	**320**	**330**	**350**	**350**	**360**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-150 000**	**7 600**	**-85 000**	**-33 000**	**-44 000**
a. Forest Land	**-190 000**	**-22 000**	**-110 000**	**-58 000**	**-69 000**
b. Cropland[2]	**23 000**	**19 000**	**16 000**	**15 000**	**14 000**
c. Grassland	**5 000**	**5 000**	**5 000**	**5 000**	**5 000**
d. Wetlands	–	–	–	–	–
e. Settlements	**6 000**	**6 000**	**6 000**	**6 000**	**6 000**

Notes:

1 National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

2 CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Totals may not add due to rounding.

ES.3.2.2 Long-Term Trends

Although the long-term (1990–2003) sectoral emission trends showed declines and increases, the increases were well ahead of the declines, for a net growth of 144 Mt, or 24%. The largest portion of the growth is observed in the Energy Sector, where the Fossil Fuel Industries, Mining, Electricity and Heat Generation, Road Transportation, and Commercial & Institutional categories made the greatest contributions.

The activities of the fossil fuel industries embrace both combustion sources (Fossil Fuel Industries and Pipelines) and fugitive sources (Coal Mining and Oil and Natural Gas). There is also some overlap with Mining, which (as a result of categorizations by the Alberta Utilities Energy Board and Statistics Canada) includes a portion of oil sands production activities.

The oil and gas industries, representing by far the largest portion of the fossil fuel industries, registered a net increase of close to 50 Mt of GHG emissions from 1990 to 2003 (42% growth).[9] These emissions are related to the production, transmission, processing, refining, and distribution of all oil and gas products.

Over the period, total production of crude oil and natural gas increased by 61%, with an attendant 45% increase in subsector GDP.[10] Increasing demand in both Canada and the United States drove these trends, with the export market growing by far the most rapidly (see Section ES.4.1). In opposition to the longer-term trend, total production increased by less than 1% between 2002 and 2003 and emissions fell, but it is unclear if this one-year change has implications for the longer term.

As with the Fossil Fuel Industries, Mining showed a large increase in emissions between 1990 and 2003 — close to 8 Mt (over 100% growth), when excluding the portion related to oil sands activities — on the basis of a 36% growth in sector GDP.

Rising demand for electricity, exacerbated by the increasing use of fossil fuels in the generation mix, drove GHG emissions up by 39 Mt between 1990 and 2003. In 2003, electricity production was 100 TWh over the 1990 level. Although hydroelectricity generation increased by 41 TWh over the period, coal generation was up by 29 TWh as well. Natural gas-fired generation, with about one-half of the GHG intensity (emissions per kWh) of that of coal-fired, was responsible for 25 TWh of the increase. By 2003, hydropower's share of the generation mix had fallen from 63% to 59%, while coal's had risen from 16% to 19% and natural gas's from 2% to 6%, worsening the average intensity of Canadian electricity generation. The end result was that from 1990 to 2003, generation rose by 21%, while GHG emissions increased by 41%, almost double the generation increase.

Emissions from Road Transportation rose by 33 Mt (31%) between 1990 and 2003. Of particular note in this subsector is a 20.2 Mt increase in emissions from LDGTs. This was partially offset by 4 and 1 Mt emission reductions from gasoline and alternatively fuelled cars (Light-Duty Gasoline Vehicles [LDGVs] and Propane & Natural Gas Vehicles), respectively.

The source of this net trend of rising emissions is the increase in the number of passenger-kilometres travelled (more people drove further) (NRCan, 2004). However, it was light trucks' passenger-kilometres that increased, while cars' showed reductions. Substantiating this is the fact that the number of light trucks on the road almost doubled between 1990 and 2003, while the number of automobiles contracted slightly. Since light trucks have higher emissions per kilometre than automobiles, the rising popularity of SUVs and pickups worsened the emission impact of increasing numbers of people driving further. Nevertheless, if the occupancy rate of lighter trucks has been higher than that of cars (and evidence suggests that it has; NRCan, 2004), then the effect of this emission difference has been reduced.

Emissions from HDDVs (large freight trucks) rose by about 17 Mt between 1990 and 2003, a 70% increase. Spurred on by free trade and the deregulation of the trucking industry, the amount of freight shipped internationally grew rapidly over the period. In addition, the quantity shipped by truck (as opposed to other modes of transport such as rail) increased as a result of customer requirements for just-in-time delivery and cross-border freight (NRCan, 2004).

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[9] Relative to the categorizations of Table S-3, the oil and gas industry emissions discussed here include Petroleum Refining, Fossil Fuel Production (minus coal), all Oil and Natural Gas fugitives, and that part of Mining representing the oil sands. Since the industry also produces CO_2 from certain chemical processes, a portion of Industrial Process emissions (about 4 Mt of that categorized under Other and Undifferentiated Production) is included as well. See the analysis presented in Annex 10.

[10] Source for all sector economic growth figures: Informetrica Limited (2005).

The Commercial & Institutional category displayed a 13 Mt (50%) growth in GHG emissions between 1990 and 2003. Driving this trend was a 26% increase in the floor space of commercial and institutional buildings (e.g., offices, schools, stores, and government edifices), a result of Canada's growing economy over the period. There was also a change in the mix of building types, with a reduction in warehouse floor space and an increase in that for offices. The increase in office space has led to rising demand for space heating and cooling.

Two more sectors that contributed, though to a lesser extent than Energy, to the longer-term growth in GHG emissions are Agriculture and Waste. Agriculture showed a 10 Mt increase (19%) between 1990 and 2003, resulting primarily from the expansion of the beef cattle, swine, and poultry industries, as well as an increase in synthetic nitrogen fertilizer consumption.

With respect to waste, CH_4 emissions from landfills (classed as Solid Waste Disposal on Land) contributed 5 Mt to the emission growth trend from 1990 to 2003. This 28% increase occurred despite a 48% increase in landfill gas capture and combustion. Over the period, per capita emissions increased by 11%. Emission growth exceeded population growth because material landfilled in past decades is still contributing to CH_4 production. Nevertheless, the gas capture and combustion systems are making an impact — it is estimated that these systems reduced emissions by more than 6.5 Mt in 2003.

In addition to the already-mentioned reduction in emissions from automobiles, two more subsectors, both within Industrial Processes, contributed significantly towards counteracting 1990–2003 emission growth — Adipic Acid Production (Chemical Industry) and Aluminium Production.

While output increased at the sole adipic acid production plant in Canada, the installation of an emission abatement system in 1997 resulted in a reduction of N_2O emissions of 9.6 Mt (90%) over the 1990–2003 period.

In the aluminium industry (which emits both CO_2 and PFCs), PFC emissions were reduced as a result of better control of anode events in smelters by increasing use of electronic monitoring and automated emission controls. As a result, between 1990 and 2003, total GHG process emissions from the aluminium industry decreased by 1.6 Mt (18%), while primary aluminium production increased by 78% (NRCan).

ES.4 OTHER INFORMATION

ES.4.1 EMISSIONS ASSOCIATED WITH THE EXPORT OF OIL AND NATURAL GAS

Growth in oil and gas exports, almost all to the United States, contributed significantly to emission growth[11] between 1990 and 2003. In this period, net oil exports (exports minus imports) grew by 466% to 1452 petajoules (PJ)[12] (almost 10 times the rate of growth of oil production) (Table S-4), while net exports of natural gas increased 132% to 3506 PJ (almost twice the rate of growth of natural gas production) (Table S-5). Over the period, the sum total of net oil and gas energy exports increased by 180% (Table S-6).

The portion of emissions from all oil and gas production, processing, and transmission activities that is attributable to net exports[13] rose from about 22 Mt in 1990 to 46 Mt in 2003 (a 115% increase).[14] This 25 Mt increase is half of the total 50 Mt growth in emissions from the oil and gas industry over the period.

As indicated above, between 2002 and 2003, natural gas exports uniquely fell, while growth in net crude oil exports lessened somewhat, so net energy exports fell. The emission impact was a reduction, by about 5 Mt.

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[11] The source for all export and energy production data is Statistics Canada, #57-003. The 1990–1995 GHG emissions associated with net exports are taken from a report prepared for Environment Canada (McCann, 1997), while the 1996–2002 estimates were extrapolated from this report.

[12] A petajoule (PJ) is a measure of the energy content of fuels.

[13] Net export emissions are the Canadian emissions associated with extracting, processing, and transporting of exported fuel minus the Canadian emissions associated with transporting and processing imported fuels.

[14] Absolute emissions attributable to net exports are rough approximations. The long-term trends are considered to be more accurate.

TABLE S-4: Crude Oil: Production, Net Export, and GHG Emission Trends, 1990–2003

Crude Oil	1990	1995	2000	2001	2002	2003
Domestic Production (PJ)	**3562**	**4170**	**4669**	**4747**	**5080**	**5427**
Growth Since 1990	N/A	17%	31%	33%	43%	52%
Energy Exported (PJ)	**1526**	**2466**	**3227**	**3197**	**3412**	**3596**
Growth Since 1990	N/A	62%	111%	110%	124%	136%
Net Energy Export (exports minus imports) (PJ)	**256**	**1070**	**1067**	**1017**	**1332**	**1452**
Growth Since 1990	N/A	318%	316%	297%	419%	466%
Emissions Associated with Net Exports (Mt CO_2 eq)	**8.8**	**17.8**	**16.5**	**15.9**	**19.4**	**20.7**
Growth Since 1990	N/A	102%	87%	81%	120%	135%

TABLE S-5: Natural Gas: Production, Net Export, and GHG Emission Trends, 1990–2003

Natural Gas	1990	1995	2000	2001	2002	2003
Domestic Production (PJ)	**4184**	**6129**	**7060**	**7202**	**7256**	**7025**
Growth Since 1990	N/A	47%	69%	72%	73%	68%
Energy Exported (PJ)	**1537**	**3011**	**3846**	**4120**	**4103**	**3876**
Growth Since 1990	N/A	96%	150%	168%	167%	152%
Net Energy Export (exports minus imports) (PJ)	**1513**	**2985**	**3785**	**3971**	**3962**	**3506**
Growth Since 1990	N/A	97%	150%	162%	162%	132%
Emissions Associated with Net Exports (Mt CO_2 eq)	**12.7**	**25.1**	**31.1**	**31.7**	**31.7**	**25.6**
Growth Since 1990	N/A	98%	145%	150%	150%	101%

TABLE S-6: Combined Crude Oil and Natural Gas: Production, Net Export, and GHG Emission Trends, 1990–2003

Combined Crude Oil and Natural Gas	1990	1995	2000	2001	2002	2003
Domestic Production (PJ)	**7 746**	**10 299**	**11 729**	**11 949**	**12 336**	**12 452**
Growth Since 1990	N/A	33%	51%	54%	59%	61%
Energy Exported (PJ)	**3 063**	**5 477**	**7 073**	**7 317**	**7 515**	**7 473**
Growth Since 1990	N/A	79%	131%	139%	145%	144%
Net Energy Export (exports minus imports) (PJ)	**1 769**	**4 056**	**4 851**	**4 989**	**5 294**	**4 958**
Growth Since 1990	N/A	129%	174%	182%	199%	180%
Emissions Associated with Net Exports (Mt CO_2 eq)	**21.5**	**42.9**	**47.5**	**47.6**	**51.1**	**46.2**
Growth Since 1990	N/A	100%	121%	122%	138%	115%

ES.4.2 PROVINCIAL/TERRITORIAL GREENHOUSE GAS EMISSIONS

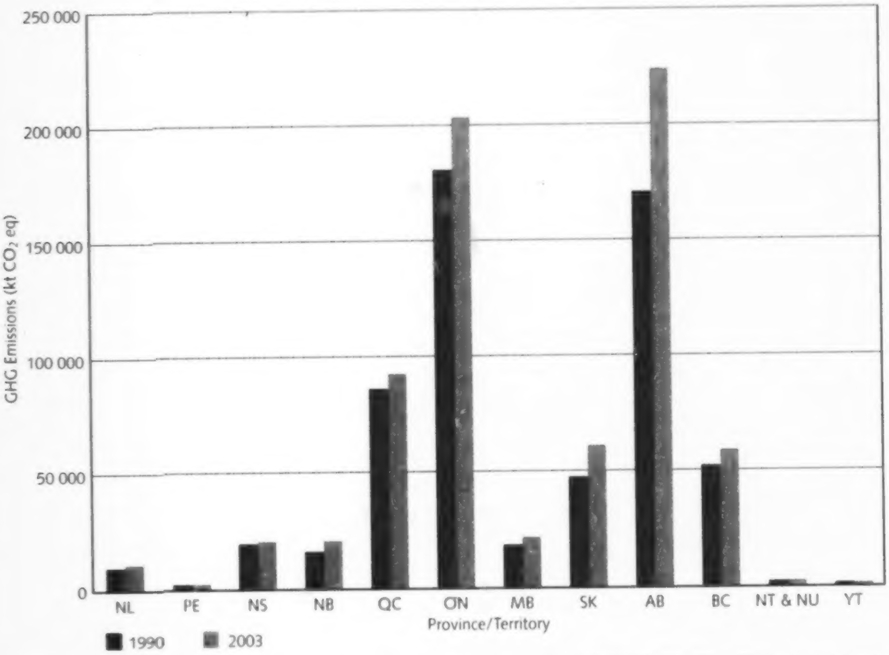
It is important to note that Canada's GHG emissions vary from region to region. This is linked to the distribution of natural resources and heavy industry within the country. While the use of natural resources and industrial products benefits all regions of North America, emissions from their production tend to be concentrated in particular geographic regions. Thus, particular jurisdictions in Canada tend to produce more GHG emissions because of their economic and industrial structure and their relative dependence on fossil fuels for producing energy. Figure S-4 illustrates the provincial/territorial distribution of emissions and the change in these emissions between 1990 and 2003.

ES.4.3 THE INTERNATIONAL CONTEXT

Canada contributes about 2% of total global GHG emissions. It is one of the highest per capita emitters, largely the result of its size, climate (i.e., energy demands), and resource-based economy. In 2003, Canada emitted over 23 t of GHGs per capita, a 9% growth since 1990 (see Table S-1).

In terms of total anthropogenic GHG emissions, Canada ranks among the 10 Annex I Parties whose emissions increased more than 10% over the 1990–2002 period.[16] Canada's +20% growth (-6% Kyoto target) compares with Spain's +40% growth (-8% target), Greece's +26% rise (-8% target), and Japan's +12% increase (-6% target). Parties whose emissions decreased by 2002 include the European Union, by -3% (-8% target), the United Kingdom, by -15% (-8% target), Germany, by -19% (-8% target), and the Russian Federation, by -38% (0% target).

FIGURE S-4: **Total Provincial/Territorial GHG Emissions, 1990 and 2003**[15]



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[15] Fuel combustion emissions from the Fossil Fuel Industries category for Alberta showed a significant increase over the period 1998–1999. This is attributed not to increased sector activity or changes in practice but to inconsistencies associated with the system for reporting the underlying fuel combustion data used in the emission calculation. Additional investigations will be undertaken to correct any year-to-year inconsistencies in the underlying data and estimated emissions in line with internationally agreed Good Practice Guidance and uncertainty management.

[16] These aggregate estimates are based on the most recent data from 37 Parties that submitted inventories to the UNFCCC in 2004. Source: UNFCCC FCCC/CP/2004/514 October 2004, p. 14, Table 4, http://unfccc.int/resource/docs/cop10/05.pdf.

1 INTRODUCTION

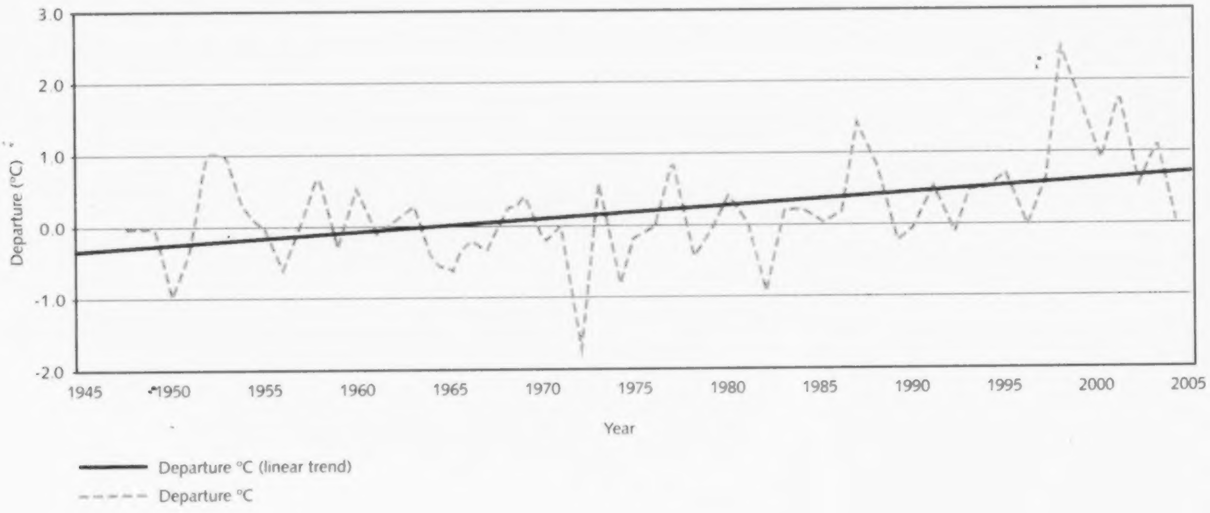
1.1 GHG INVENTORIES AND CLIMATE CHANGE

In order to understand climate change, it is important to differentiate between weather and climate. Weather is the state of the atmosphere at a given time and place and is usually reported as temperature, air pressure, humidity, wind, cloudiness, and precipitation. The term weather is used mostly when reporting these conditions over short periods of time.

On the other hand, climate is the average pattern of weather (usually taken over a 30-year time period) for a particular region. Climatic elements include precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hailstorms, and other measures of the weather.

Climate change refers to changes in long-term weather patterns caused by natural phenomena and human activities that alter the chemical composition of the atmosphere through the buildup of GHGs that trap heat and reflect it back to the Earth's surface. According to the IPCC's Third Assessment Report (IPCC, 2001b), climate change is predicted to manifest itself differently in different regions of the world. In general, temperatures and sea levels are expected to rise, and the frequency of extreme weather events is expected to increase. In some regions, the impacts could be devastating, while other regions could benefit from climate change. The impacts will depend on the form and magnitude of the change and, in the case of adverse effects, the ability of the natural and human systems to adapt to the changes. Canada's mean surface air temperature has generally been increasing nationally, with temperatures remaining above normal since 1991 (Figure 1-1).

FIGURE 1-1: **Annual Canadian Temperature Departures and Long-Term Trend, 1948–2004**



Source: Environment Canada

www.msc-smc.ec.gc.ca/ccrm/bulletin/national_e.cfm

It is now well-known that atmospheric concentrations of GHGs have grown significantly since pre-industrial times. The concentration of CO_2 has increased by 31% since 1750 (Figure 1-2), the concentration of CH_4 has increased by 151%, and the concentration of N_2O has increased by 17% (IPCC, 2001a). These trends can be largely attributed to human activities — mostly fossil fuel use and permanent loss of forest cover.

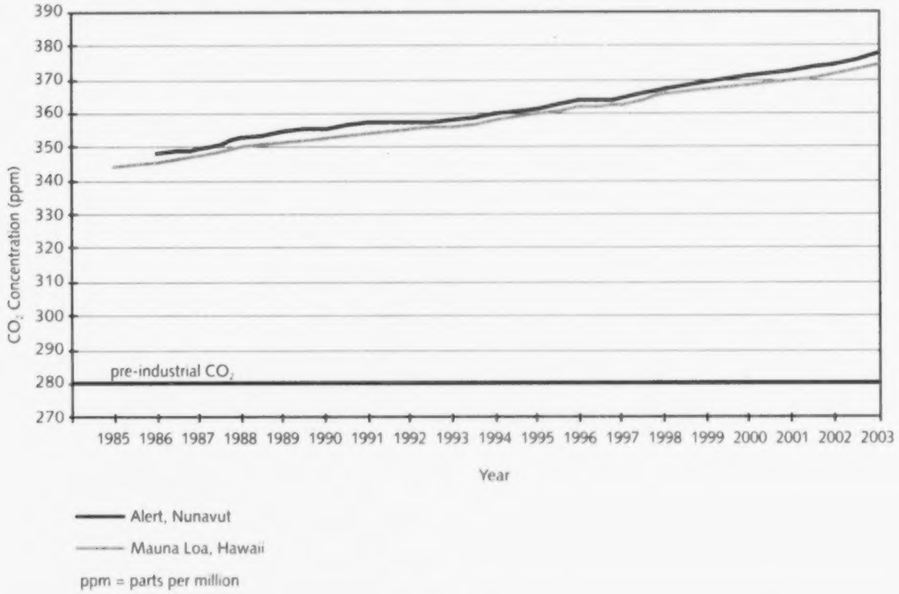
Canada tracks its contribution to the increase in these GHG concentrations by estimating its total national emissions of six GHGs covered by the UNFCCC and Kyoto Protocol.[17] This report provides estimates of Canada's emissions and removals of the following GHGs: CO_2, CH_4, N_2O, SF_6, PFCs, and HFCs. As specified by the UNFCCC, country estimates of GHG emissions relate to their human (anthropogenic) activities and do not include emissions from naturally occurring sources or sinks.

1.1.1 CARBON DIOXIDE (CO_2)

On a worldwide basis, CO_2 emissions generated from anthropogenic activities are known to be small. In comparison with the gross fluxes of carbon from natural systems, they represent only a fraction (~2%) of total global emissions. However, evidence suggests that they account for most of the observed accumulated CO_2 in the atmosphere (Sullivan, 1990; Edmonds, 1992). On the basis of global emissions information, the primary sources of CO_2 generated from anthropogenic activities are fossil fuel combustion (including both stationary and mobile sources), deforestation (resulting in permanent loss of forest cover), and industrial processes, such as cement production.

Over the 45 years leading to 1996, global emissions of CO_2 grew from about 6.4 to 23.9 gigatonnes (Gt), almost a fourfold increase (Marland et al., 1999). Deforestation, land-use practices, and ensuing soil oxidation have been estimated to account for about 23% of anthropogenic CO_2 emissions. The primary natural sources of CO_2 include respiration by plants and animals, decomposing organic matter and fermentation, volcanoes, forest/grass fires, and oceans. The two main natural carbon-balancing processes, photosynthesis in terrestrial and aquatic ecosystems and storage in ocean sediments, remove substantial amounts of CO_2 from

FIGURE 1-2: **Global Atmospheric Concentrations of CO_2, 1985–2003**



Sources: C.D. Keeling, T.P. Whorf, and the Carbon Dioxide Research Group. Scripps Institution of Oceanography (SIO), University of California. http://cdiac.esd.ornl.gov/ftp/trends/co2/

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[17] The UNFCCC and Kyoto Protocol do not cover the GHGs (e.g., chlorofluorocarbons [CFCs], hydrochlorofluorocarbons [HCFCs]) that are covered under the Montreal Protocol, the international agreement whose aim is to reduce damage to the stratospheric ozone layer.

the atmosphere. However, the absorption capacity of these natural sinks appears to be exceeded, as atmospheric concentrations of CO_2 and other GHGs are increasing.

1.1.2 METHANE (CH_4)

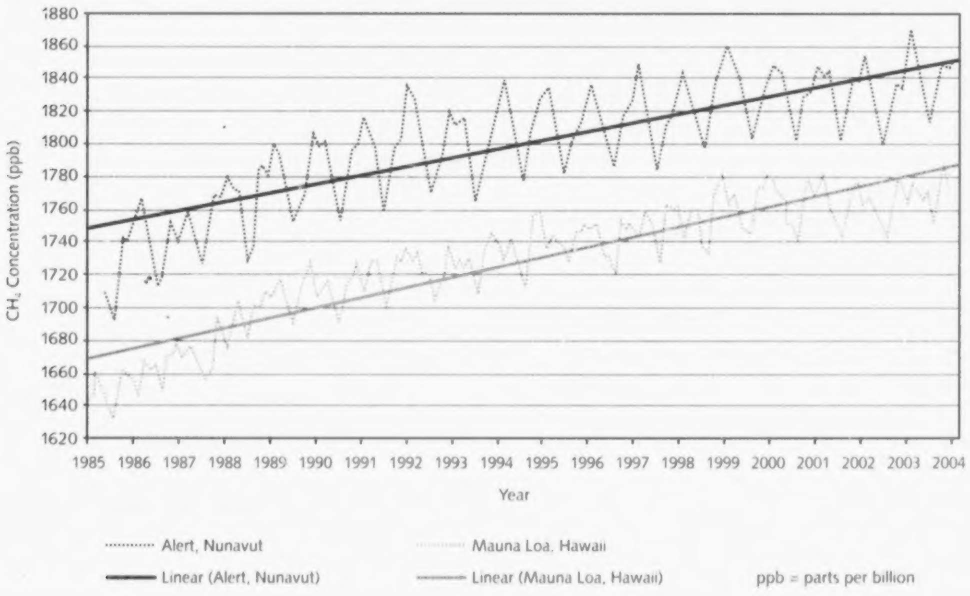
In addition to CO_2, excess global CH_4 emissions resulting from anthropogenic activities are considered to have caused an increase of about 145% in atmospheric concentrations since the mid-1700s (Thompson et al., 1992). Recent atmospheric measurements of CH_4 concentrations are shown in Figure 1-3.

The current annual rate of accumulation of CH_4 is estimated to range between 40 and 60 Mt (~14–21 parts per billion by volume, or ppbv), or approximately 10% of total worldwide CH_4 emissions (Thompson et al., 1992). CH_4 emissions generated from human activities, amounting to ~360 Mt per year, are primarily the result of activities such as livestock and rice cultivation, biomass burning, natural gas delivery systems, landfills, and coal mining (EPA, 1981). Although several uncertainties exist in the actual contributions and relative importance of these sources, emission reductions of about 8% are thought to be required to stabilize CH_4 concentrations at current levels (IPCC, 1996a).

1.1.3 NITROUS OXIDE (N_2O)

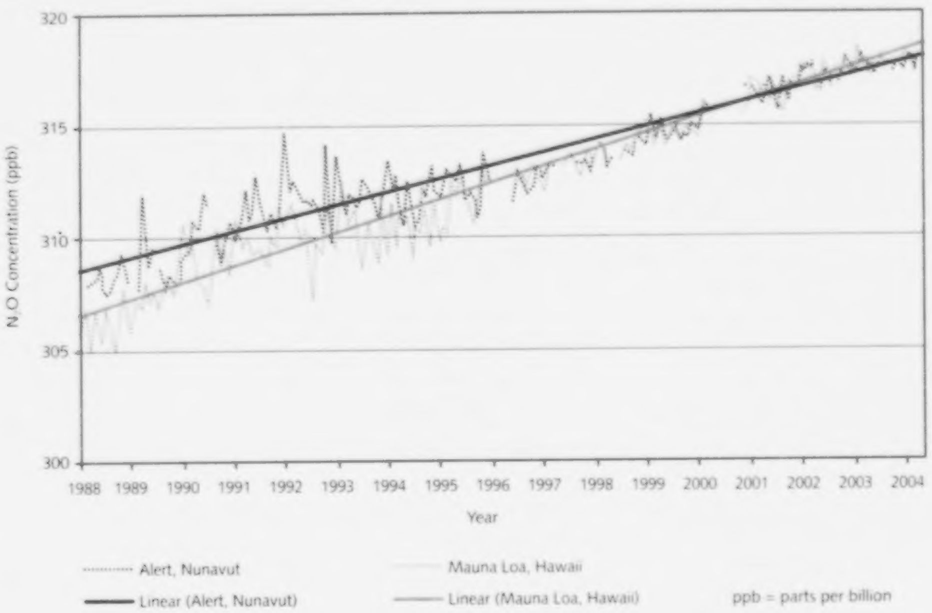
At present, it has been estimated that approximately one-third of global atmospheric N_2O is of human origin, resulting primarily from the application of nitrogen fertilizers, soil cultivation, and the combustion of fossil fuels and wood. Atmospheric concentrations of N_2O have grown by about 17% since the mid-1700s (IPCC, 2001a). Total annual emissions from all sources are estimated to be within the range of 10–17.5 Mt N_2O, expressed as nitrogen (N) (IPCC, 1996b). Figure 1-4 shows global atmospheric N_2O concentrations from 1988 to 2004. The other two-thirds of global atmospheric N_2O comes from soil and water denitrification under anaerobic conditions.

FIGURE 1-3: **Global Atmospheric Concentrations of CH_4, 1985–2003**



Source: Dr. James W. Elkins and Mr. Geoffrey S. Dutton, Climate Monitoring and Diagnostics Laboratory (CMDL), World Data Centre for Greenhouse Gases. http://gaw.kishou.go.jp/wdcgg.html

FIGURE 1-4: Global Atmospheric Concentrations of N_2O, 1988–2004



Source: Dr. James W. Elkins and Mr. Geoffrey S. Dutton, Climate Monitoring and Diagnostics Laboratory (CMDL), World Data Centre for Greenhouse Gases http://gaw.kishou.go.jp/wdcgg.html

1.1.4 HYDROFLUOROCARBONS, PERFLUOROCARBONS, AND SULPHUR HEXAFLUORIDE ($HFCs$, $PFCs$, AND SF_6)

The final group of GHGs included in this report is the synthetic (not naturally occurring) fluorinated gases HFCs, PFCs, and SF_6. These gases, while emitted in very small amounts, are having a lasting effect on atmospheric composition and, potentially, the climate, because they are strong absorbers of infrared radiation and have very long atmospheric lifetimes. As shown in Table 1-1, all of the PFCs have atmospheric lifetimes of 2600 years or greater, with perfluoromethane estimated to last 50 000 years.

1.1.5 GHGs AND THE USE OF GWPs

To understand the emission data presented in this report, it is important to understand that the radiative forcing[18] effect of a gas within the atmosphere is a reflection of its ability to cause atmospheric warming. Direct effects occur when the gas itself is a GHG, while indirect radiative forcing occurs when chemical transformation of the original gas produces a gas or gases that are GHGs or when a gas influences the atmospheric lifetimes of other gases.

The concept of "global warming potential" (GWP) has been developed to allow scientists and policy-makers to compare the ability of each GHG to trap heat in the atmosphere relative to another gas. By definition, a GWP is the time-integrated change in radiative forcing due to the instantaneous release of 1 kg of the gas expressed relative to the radiative forcing from the release of 1 kg of CO_2. In other words, a GWP is a relative measure of the warming effect that the emission of a radiative gas (i.e., GHG) might have on the surface troposphere. The GWP of a GHG takes into account both the instantaneous radiative forcing due to an incremental concentration increase and the lifetime of the gas. The 100-year GWPs, recommended by the IPCC (Table 1-1) and required for inventory reporting under the UNFCCC (adopted at the third Conference of the Parties), are used in this report.

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[18] The term "radiative forcing" refers to the amount of heat-trapping potential for any given GHG. It is measured in units of power (watts) per unit of area (metres squared).

TABLE 1-1: **GWPs and Atmospheric Lifetimes**

GHG	Formula	100-Year GWP	Atmospheric Lifetime
Carbon Dioxide	CO_2	1	Variable
Methane	CH_4	21	12 ± 3
Nitrous Oxide	N_2O	310	120
Sulphur Hexafluoride	SF_6	23 900	3 200
Hydrofluorocarbons (HFCs)			
HFC-23	CHF_3	11 700	264
HFC-32	CH_2F_2	650	5.6
HFC-41	CH_3F	150	3.7
HFC-43-10mee	$C_5H_2F_{10}$	1 300	17.1
HFC-125	C_2HF_5	2 800	32.6
HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	1 000	10.6
HFC-134a	$C_2H_2F_4$ (CH_2FCF_3)	1 300	14.6
HFC-143	$C_2H_3F_3$ (CHF_2CH_2F)	300	1.5
HFC-143a	$C_2H_3F_3$ (CF_3CH_3)	3 800	3.8
HFC-152a	$C_2H_4F_2$ (CH_3CHF_2)	140	48.3
HFC-227ea	C_3HF_7	2 900	36.5
HFC-236fa	$C_3H_2F_6$	6 300	209
HFC-245ca	$C_3H_3F_5$	560	6.6
Perfluorocarbons (PFCs)			
Perfluoromethane	CF_4	6 500	50 000
Perfluoroethane	C_2F_6	9 200	10 000
Perfluoropropane	C_3F_8	7 000	2 600
Perfluorobutane	C_4F_{10}	7 000	2 600
Perfluorocyclobutane	$c\text{-}C_4F_8$	8 700	3 200
Perfluoropentane	C_5F_{12}	7 500	4 100
Perfluorohexane	C_6F_{14}	7 400	3 200

Note:

The CH_4 GWP includes the direct effect and those indirect effects due to the production of tropospheric ozone and stratospheric water vapour. Not included is the indirect effect due to the production of CO_2.

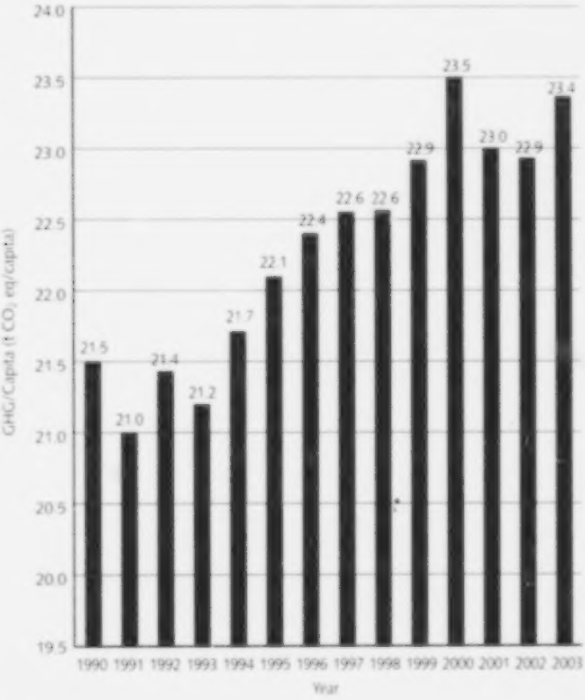
Sources:

GWP: IPCC (1996a).
Atmospheric Lifetime: IPCC (1995), Table 2.9, p. 121.

1.1.6 CANADA'S CONTRIBUTION

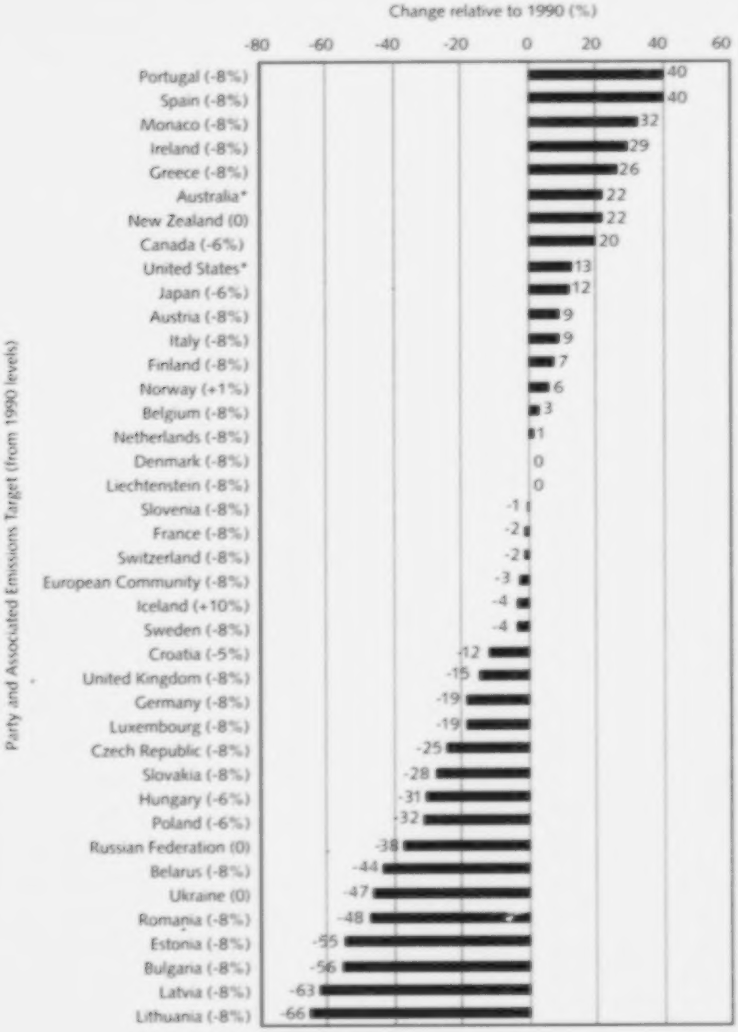
While Canada contributes only about 2% of total global GHG emissions, it is one of the highest per capita emitters, largely the result of its size, climate (i.e., energy demands), and resource-based economy. In 1990, Canadians released 21.5 t of GHGs per capita. Over the 13-year period from 1990 to 2003, this increased to 23.4 t of GHGs per capita (Figure 1-5).

FIGURE 1-5: **Trend in Canada's per capita GHG Emissions, 1990–2003**



In terms of total anthropogenic GHG emissions, Canada ranks among the 10 Annex I Parties whose emissions increased more than 10% over the 1990–2002 period (Figure 1-6). These aggregate estimates are based on data from 37 Parties that submitted inventories to the UNFCCC in 2004 and on carrying forward the last reported inventory data taken from inventory submissions or national communications for those Parties where 2002 data were not reported.

FIGURE 1-6: Change in Aggregate GHG Emissions for Annex I Parties, 1990–2002



Note: Changes are with respect to 2002 or the most recent year for which data were available.

* Countries that have not ratified the Kyoto Protocol.

Source: UNFCCC FCCC/CP/2004/5 14 October 2004, p. 14, Table 4.
http://unfccc.int/resource/docs/cop10/05.pdf

1.2 INSTITUTIONAL ARRANGEMENTS FOR INVENTORY PREPARATION

The Department of the Environment (Environment Canada) is responsible for monitoring and reporting on the environment in Canada. The GHG Division of Environment Canada is Canada's central inventory agency and, as such, prepares and compiles the national GHG inventory for Canada. Underlying data used to prepare the inventory are collected by Environment Canada from a variety of agencies, including Statistics Canada (e.g., energy data, livestock, crop production, and land statistics), Natural Resources Canada (NRCan) (e.g., mineral production and forestry statistics), Agriculture and Agri-Food Canada (e.g., agricultural soil model results), as well as other sections of Environment Canada (e.g., landfill gas capture, HFC and PFC use data).

Statistics Canada and Environment Canada have legislated mandatory reporting provisions to ensure consistent reporting. The majority of the data collected by Statistics Canada (and used as activity data for the inventory) are mandatory and collected under the authority of the *Statistics Act*. To improve the accuracy of the inventory, Environment Canada has established a formal agreement (Memorandum of Understanding) with Statistics Canada to provide Environment Canada with access to confidential facility-level information, which in turn helps to improve the quality of the inventory. Environment Canada uses mandatory reporting provisions of the *Canadian Environmental Protection Act, 1999* (CEPA 1999) to collect HFC and PFC use data. The remainder of the data collected for the inventory are reported in a non-mandatory manner. Section 1.4 describes new provisions for reporting GHG emissions by Canada's major emitters.

Clear roles have been established between the two main departments active in climate change: Environment Canada and NRCan. This has been agreed to in a Memorandum of Understanding between the GHG Division of Environment Canada and the Analysis and Modelling Division of NRCan. Under the agreement, Environment Canada prepares and compiles the national GHG inventory, and NRCan is responsible for preparing GHG emission forecasts. The GHG Division chairs an interdepartmental committee on the Monitoring, Accounting and Reporting System (MARS) for LULUCF.[19] The mandate of this committee is to coordinate the activities of Environment Canada, NRCan (the Canadian Forest Service), and Agriculture and Agri-Food Canada so that the necessary accounting systems can be developed that will allow Canada to meet both UNFCCC and Kyoto Protocol reporting requirements for LULUCF.

Prior to its submission to the UNFCCC, the inventory is reviewed by the Emissions and Projections Working Group (EPWG) and other selected government experts. The EPWG is used to coordinate emission inventory activities in Canada and is made up of provincial/territorial and federal government representatives working in the field of air pollution measurement and estimation.

1.3 PROCESS FOR INVENTORY PREPARATION

The data used to compile the national inventory are generally from published sources. Data are collected either electronically or manually (hard copies) from the source agencies and are entered into a spreadsheet-based emission accounting system or model. Emissions are calculated by designated inventory experts, reviewed internally, and then reported according to UNFCCC guidelines in the CRF and the NIR. The inventory group also carries out QC procedures, documentation, uncertainty estimation, key category assessment, and trends analysis.

A draft inventory is distributed in a formal review process to the interdepartmental EPWG. In addition, the emission estimates for the Energy, Industrial Processes, and Agriculture sectors are reviewed in detail by other government departments, such as NRCan and Agriculture and Agri-Food Canada, while the Waste Sector emissions are reviewed by other experts within Environment Canada.

Comments from the review are incorporated, and the initial submission is made electronically by April 15 of each year. The CRF and NIR are then further edited, translated, and published, and a final submission is prepared in late summer.

1.4 METHODOLOGIES AND DATA SOURCES

The inventory is structured to match the reporting requirements of the UNFCCC and is divided into six main sectors:

- Energy;
- Industrial Processes;
- Solvent and Other Product Use;
- Agriculture;
- LULUCF; and
- Waste.

Each of these sectors is further subdivided within the inventory. The methods described have been grouped, as closely as possible, by UNFCCC sector and subsector.

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[19] See website: www.ec.gc.ca/pdb/ghg/mars_steering_committee_e.cfm

The methodologies contained in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/OECD/IEA, 1997), *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000), and *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003) are followed to estimate emissions and removals of each of the following direct GHGs:

- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- hydrofluorocarbons (HFCs);
- perfluorocarbons (PFCs); and
- sulphur hexafluoride (SF_6).

While not mandatory, the new UNFCCC Reporting Guidelines encourage Annex I Parties to provide information on the following indirect GHGs:

- sulphur oxides (SO_x);
- nitrogen oxides (NO_x);
- carbon monoxide (CO); and
- non-methane volatile organic compounds (NMVOCs).

For all categories except LULUCF, these gases (referred to as the Criteria Air Contaminants [CACs]) are inventoried and reported separately. CAC emissions in Canada are reported to the United Nations Economic Commission for Europe (UNECE)[20]; however, information on CACs is now also included in the NIR (see Annex 15: Ozone and Aerosol Precursors).

In general, an emission inventory can be defined as a comprehensive account of air pollutant emissions and associated data from sources within the inventory area over a specified time frame. It can be prepared "top-down," "bottom-up," or using a combination approach. Canada's national inventory is prepared using a "top-down" approach, providing estimates at a sectoral and provincial/territorial level of segregation without attribution to individual emitters. Environment Canada is continuously working to improve the accuracy, completeness, and transparency of its inventory. A comprehensive bottom-up inventory is neither practicable nor possible at the present time.

The inventory distinguishes between point and area sources. Point sources refer to individual sources or facilities, whereas area sources are spatially diffuse and/or very numerous, involving the gathering of information on many individual sources. Point source emissions may be measured or estimated from information assembled from individual plant or facility throughput and emission factors.

Emissions or removals — whether for point or for area sources — are usually calculated or estimated using mass-balance approaches or stoichiometric relationships under averaged conditions. In many cases, provincial/territorial activity data are combined with average emission factors to produce a "top-down" national inventory. Large-scale regional estimates under averaged conditions have been compiled for diffuse sources such as transportation. Emissions from landfills are determined using a simulation model to account for the long-term slow generation and release of these emissions.

Manipulated biological systems, such as agricultural lands, forestry, and land converted to other uses, are typical sources or sinks diffused over very large areas. Processes that cause emissions and removals display considerable spatial and interannual variability, and they also span several years or decades. The most practical approach to estimating emissions and removals may require a combination of repeated measurements and modelling. The need, unique to these systems, to separate anthropogenic impact from large natural fluxes creates an additional challenge.

In general, GHG emission and removal estimates may be derived for a given process or combination of operations by one or more of the following methods:

- *Direct Measurement*: With few exceptions, GHG emission or removal measurements apply to point sources. At present, a very limited number of sources have measured and reported GHG emissions.
- *Mass Balance*: This approach determines atmospheric emissions from the difference between the amounts of the component (e.g., carbon) contained in feed materials or fuels and that contained in the

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[20] See website: http://webdab.emep.int/

products, process wastes, or non-emitted residuals. Mass balances are most appropriately applied to fuel carbon contributions and mineral processing activities, where sufficient data are available to derive average carbon contents of process streams. Generally, CO_2 emissions resulting from fuel combustion are readily estimated by the carbon balance method.

- *Technology-Specific Emission Factor Calculations*: Company-specific emission factors can be used to estimate the rate at which a pollutant is released into the atmosphere (or captured) as a result of some process activity or unit throughput. Although emissions or removals may not be measured, individual facilities may have measured rate data for various parameters for their plant. These can be combined with other plant-specific information, such as throughput, activity data, and the number of such sources, to derive plant-specific emissions or removals for a point source or "bottom-up" inventory.
- *Average or General Emission Factor Calculations*: Where plant-specific data are not available, average or general-use emission factors can be used for a given source or sector. These can be combined with company-specific, sector-specific, process-specific, or general activity and population data to calculate emissions for a top-down inventory. Average or general emission factors for most of the sectors in the inventory have been developed by Environment Canada, in consultation with other government departments, industry associations, and other agencies and organizations. These values reflect the most accurate methodologies based on currently available data and include information currently being developed by the IPCC for the UNFCCC.

The methodologies and emission factors described in this document are considered to be the best available to date given the available activity data. That being said, in some cases, a more accurate method or emission factor may be available, but the necessary activity data are lacking at the national level, so the more accurate method cannot be used. Some methods have undergone revision and improvement over time, and some new sources have been added to the inventory over time.

For the 2003 inventory year, a number of changes mandated by the reporting provisions of the Kyoto Protocol have been instituted in compiling the NIR. CO_2 emissions from agricultural soils and non-CO_2 emissions from forest fires are now reported within the LULUCF Sector (previously LUCF). Since the national inventory totals exclude GHG emissions and removals from the LULUCF Sector, these categories, previously included in the national totals, are now excluded. In addition, estimates for emissions from the aluminium production industry, which appear under Industrial Processes – Metal Production, have been revised, as has the method of allocating emissions between domestic and international aviation. For further information, please refer to Chapter 9: Recalculations and Improvements.

As Canada begins to implement a number of measures outlined in the Climate Change Plan 2005 (Government of Canada, 2005), the level of detail in the national inventory will increase. A mandatory domestic GHG reporting system has been launched to serve Canada's domestic interests (federal, provincial/territorial, and public information needs), which require a means to measure, track, and report progress on the reduction of GHG emissions that is accurate, transparent, and credible. The reporting system was launched on March 15, 2005. All persons who operated a facility that emitted, in calendar year 2004, 100 kilotonnes of carbon dioxide equivalent (100 kt CO_2 eq) or more of GHGs (the "reporting threshold") are required to complete and submit their report by June 1, 2005. The Government of Canada also announced in March 2005 the requirement for facilities to submit a report in 2006 if their 2005 GHG emissions meet or exceed the reporting threshold.

The GHG reporting system collects facility-level emission data to support domestic policy objectives. It will also allow Canada to enhance the detail and precision of the annual GHG inventory reported internationally.

Statistics Canada, as the selected reporting vehicle for the GHG reporting system, will jointly collect the information under the authority of the *Statistics Act*, as well as CEPA 1999 and the *Climate Change and Emissions Management Act* (Government of Alberta). Statistics Canada will be providing the facility emission data to the Minister of Environment, who has indicated the intent to publish the data (except for confidential data protected under CEPA 1999).

These initiatives strongly underscore the partnerships between federal, provincial, and territorial governments in implementing a single-window domestic reporting system that is efficient and well-harmonized. Implementing the reporting system in orderly phases will help to ensure that a fully developed and tested system is in place by the start of the first Kyoto Protocol commitment period (2008–2012).

1.5 KEY CATEGORIES

For the 1990–2003 GHG inventory, level, trends, and qualitative key category assessments were performed on the inventory according to the Tier 1 approach as presented in the IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000) and the IPCC *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003). The emission and removal categories used for the key category assessment generally follow those in the CRF and the LULUCF CRF; however, they have been aggregated in some cases and are specific to the Canadian inventory.

Major key categories based on the level and trend assessments (including LULUCF) are the fuel combustion categories (for Road Transportation, Electricity and Heat Generation, and other subsectors) and the LULUCF category Forest Land Remaining Forest Land. Details and results of the assessments are presented in Annex 1.

1.6 QA/QC

The application of QA/QC procedures is an essential requirement in the GHG inventory development and submission processes. The goal is to improve and strive to ensure transparency, consistency, comparability, completeness, and confidence in the national emission and removal estimates for the purposes of meeting Canada's reporting commitments under the UNFCCC. For many years, informal QC of the inventory has been performed. The design of a formal QA/QC plan meeting the UNFCCC and IPCC standards has been initiated with the development of a QA/QC framework providing for a full suite of QC (both Tiers 1 and 2) and QA (review and audits) procedures to be applied to the inventory. The QA/QC plan will be further elaborated over the next inventory cycle. The full quality management cycle, particularly this first iteration, will span several years. For this submission, formal Tier 1 QC procedures were implemented and documented for 39 categories (34 of which are part of the 42 key categories and 5 are non-key categories, 2 of which have been subject to a change in methodology). Formal QA was performed, as prior to each submission annually, with the EPWG review. The reader is referred to Annex 6 of this report for more information.

1.7 INVENTORY UNCERTAINTY

While national GHG inventories should be accurate, complete, comparable, transparent, and verifiable, estimates will always inherently carry some uncertainty. Uncertainties in the inventory estimates may be caused by systematic model uncertainty or (more likely) may be due to random uncertainties present within the input parameters. While improvements to model uncertainties need more frequent performance of in-depth reviews on the estimation models, random uncertainties may be reduced by improvements to the activity data regimes and to the processes of evaluation of emission factors and other model parameters.

The UNFCCC Reporting Guidelines on Annual Inventories state that Annex I Parties shall quantitatively estimate uncertainties in data for all source and sink categories using at least the Tier 1 method, as provided in the IPCC Good Practice Guidance. Parties may use the Tier 2 method in the IPCC Good Practice Guidance to address technical limitations in the Tier 1 method. The guidelines also require that uncertainty in the data used for all source and sink categories be qualitatively discussed in a transparent manner in the NIR, in particular for those categories identified as key.

In this NIR, Canada presents the results of a Tier 2 quantitative study of uncertainty as performed on key source categories and the inventory as a whole during the period of 2004–2005. Although the study of uncertainty was performed on the 2001 NIR data, the level uncertainties assessed are assumed to be representative of the current inventory uncertainty for the majority of cases. Annex 7 provides for details of uncertainty estimates for all sectors except LULUCF (for which the Good Practice Guidance was under development at the time of study). Explanation of drivers of uncertainty for various categories and the

Canadian inventory analysts' interpretation of the results from the study are provided within sector-specific chapters.

The overall level uncertainty of the national inventory (without LULUCF) currently falls within a range of -3% to +6% for all GHGs combined without consideration of the uncertainty within the GWPs (ICF, 2005). With GWP uncertainty considered, the overall uncertainty falls within a range of -5% to +10% (ICF, 2005). In regards to the particular GHGs, N_2O exhibits the highest uncertainty range in the national inventory, with a range of -8% to +80%, followed by HFCs, with a range of -22% to +58%. The largest contributor to the inventory, CO_2, exhibits an uncertainty of -4% to 0%. For uncertainty information on other gases, reference should be made to Annex 7. The Canadian inventory's uncertainty estimate falls within the range of uncertainty as reported by other Annex I countries.

1.8 COMPLETENESS ASSESSMENT

The national GHG inventory, for the most part, is a complete inventory of the six GHGs required under the UNFCCC. Some minor sources not included in Canada's 2002 inventory are now included, such as SF_6 from electrical equipment and magnesium foundries. In the LULUCF sector, UNFCCC Decision 13/CP.9 entails new reporting requirements that have not yet been fully met. As part of the improvement plan, efforts are continuously being made to identify and assess relevant new sources and sinks for which cost-effective estimation methods are available. Further details on the completeness of the inventory can be found in the assessment of completeness (Annex 5).

1.9 IMPLICATIONS OF THE KYOTO PROTOCOL ENTERING INTO FORCE

The Kyoto Protocol to the UNFCCC entered into force on February 16, 2005, in accordance with the provisions of its Article 25. The entry into force of the Protocol will have immediate implications on reporting and review requirements. Annex I countries must:

- have in place, no later than 2007, national systems for estimating GHG emissions by sources and removals by sinks using agreed upon methodologies as outlined in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/OECD/IEA, 1997), *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000), and *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003);
- submit annual GHG inventories as well as national communications to demonstrate compliance. The fourth national communications are due by January 1, 2006;
- demonstrate progress in achieving commitments under the Protocol. Canada's target is an overall reduction of GHG emissions to 6% below 1990 levels in the commitment period 2008–2012; and
- help developing countries develop capacity to respond to climate change.

2 GREENHOUSE GAS EMISSION TRENDS, 1990–2003

2.1 SUMMARY OF EMISSION TRENDS

In 2003, Canada's GHG emissions were 740 Mt,[21] which is a 24% increase over 1990 emissions. Between 2002 and 2003, emissions grew by 3.0%. Over the year, there were increased emissions in the Mining, Commercial & Institutional, Domestic Aviation, Consumption of Halocarbons and SF_6, Agricultural Soils, Electricity and Heat Generation, and Construction subsectors. Between 2002 and 2003, reductions were seen mainly in the areas of Fossil Fuel Industries, Pipelines, Chemical Industry, and Metal Production.

Since 1990, growth in emissions resulted primarily from Electricity and Heat Generation and areas such as Fossil Fuel Industries, Mining, Transportation, Consumption of Halocarbons and SF_6, Enteric Fermentation, and Waste. There have been overall decreases in Manufacturing Industries and Construction (excluding Mining), the Chemical Industry, and Metal Production.

2.2 EMISSION TRENDS BY GAS

CO_2 is, by far, the largest contributor to Canada's GHG emissions. Figure 2-1 shows how little the percent contributions of the six GHGs have changed between 1990 and 2003. CO_2 has changed only slightly in proportion, from 77% of emissions in 1990 to 79% in 2003.

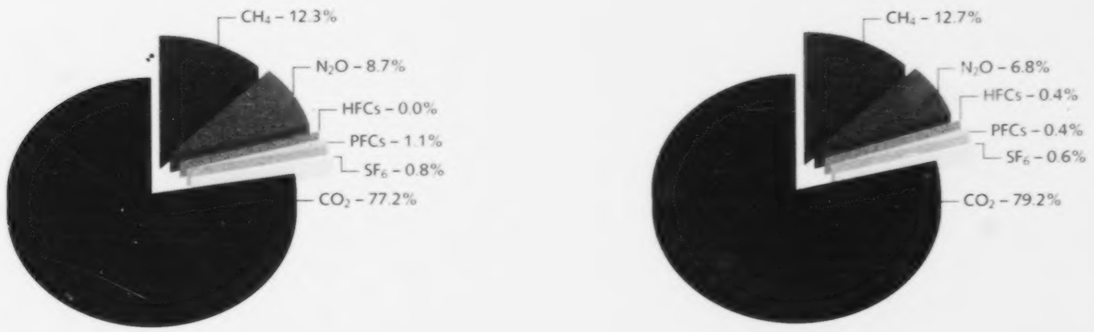
2.3 EMISSION TRENDS BY SOURCE

2.3.1 ENERGY SECTOR (2003 GHG EMISSIONS, 600 Mt)

Energy-related activities are by far the largest source of GHG emissions in Canada. The Energy Sector includes emissions of all GHGs from the production of fuels and their combustion for the primary purpose of delivering energy. Emissions in this sector are classified as either fuel combustion or fugitive releases. Fugitive emissions are defined as intentional or unintentional releases of GHGs from the production, processing, transmission, storage, and delivery of fossil fuels.

Overall, fuel combustion and fugitive emissions accounted for 81% of total Canadian GHG emissions in 2003 (546 Mt and 54 Mt, respectively). Between 1990 and 2003, fuel combustion-related emissions increased 27%, while emissions from fugitive releases rose 42%. Five-year and year-to-year changes in both fuel combustion and fugitive emissions through the period 1990–2003 are shown in Table 2-1.

FIGURE 2-1: **Canada's GHG Emissions by Gas, 1990 and 2003**



1990

2003

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[21] Unless explicitly stated otherwise, all emission estimates given in Mt represent emissions of GHGs in Mt CO_2 equivalent.

The energy industries, grouped in the Energy Sector, contribute more than any other category to Canada's emissions. These industries (consisting of fossil fuel production and electricity and heat production) generate both combustion and fugitive emissions. In terms of Table 2-1, these industries encompass the "Fuel Combustion – Energy Industries" category and the "Fugitive Emissions from Fuels" category. Altogether, the energy industries contributed 260 Mt or 35% of Canada's total and about 43% of the Energy Sector's emissions for 2003.

TABLE 2-1: **Energy GHG Emissions by UNFCCC Sector, 1990–2003**

GHG Source Category	1990	1995	2000	2002	2003
			(Mt)		
1. Energy	**469**	**508**	**582**	**583**	**600**
A. Fuel Combustion (Sectoral Approach)	**431**	**459**	**528**	**529**	**546**
1. Energy Industries	147	156	199	202	206
2. Manufacturing Industries and Construction	63.0	62.1	64.6	62.2	66.2
3. Transport	150	160	180	180	190
4. Other Sectors	72	77	81	81	87
B. Fugitive Emissions from Fuels	**37.9**	**49.8**	**54.0**	**54.5**	**54.0**
1. Solid Fuels (Coal)	2	2	1	1	1
2. Oil and Natural Gas	36.0	48.1	53.0	53.5	53.0

Table 2-1 divides energy sources by UNFCCC category — Fuel Combustion is categorized separately from Fugitive Emissions. By this breakdown, fuel combustion in the Energy Industries accounted for 206 Mt in 2003, while fugitive emissions were responsible for 54 Mt. In terms of growth, Fugitive Emissions from Fuels (including production, transmission, and distribution activities) have increased more than any other category in Energy — between 1990 and 2003, they rose by 42%.

2.3.1.1 Emissions from Fuel Combustion (2003 GHG emissions, 546 Mt)

GHG emissions from fuel combustion rose from 431 Mt in 1990 to 546 Mt in 2003, a 27% increase. Fuel combustion emissions are divided into the following UNFCCC categories: Energy Industries,[22] Manufacturing Industries and Construction, Transport, and Other Sectors. The "Other Sectors" category comprises emissions from the residential and commercial subsectors, as well as minor contributions of stationary fuel combustion emissions from agriculture and forestry.

Energy Industries (2003 GHG emissions, 206 Mt)

The Energy Industries subsector accounts for the largest source of fuel combustion emissions (28%) of Canada's total. Emissions included in this subsector are from stationary sources and from the production, processing, and refining of energy (electricity generation, oil and natural gas production, refining of petroleum products, etc.). In 2003, combustion emissions from this subsector totalled 206 Mt, an increase of 40% from the 1990 level of 147 Mt. UNFCCC categories within this subsector include public electricity and heat production, petroleum refining, and manufacture of solid fuels and other energy industries.

- **Public Electricity and Heat Production[23] (2003 GHG emissions, 134 Mt)**

This category accounted for 18% (134 Mt) of Canada's 2003 GHG emissions and was responsible for 27% of the total emissions growth between 1990 and 2003. Overall, emissions increased 41%, or almost 39 Mt, since 1990.

Hydroelectric and coal-fired generation continue to be the major sources of Canadian electricity, accounting for 59% and 19%, respectively, of total national generation in 2003. Nuclear energy provided 12%, natural gas about 6%, and oil 3%. Of this total, a little over 8% was produced by industrial, non-utility generating sources. In comparision, in 1990, coal accounted for 16% of Canadian electricity generation, oil 3%, natural gas 2%, nuclear energy 15%, and hydro 63%. Total annual production increased by 21% between 1990 and 2003. This rate of growth exceeds the population growth rate of 14.2% for the same period, pointing to an increase in demand from economic sectors that depend on electric power.

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[22] The UNFCCC Energy Industries subsector is composed of the following NIR sectors: *fossil fuel industries, electricity* and *heat generation*, and *manufacturing of solid fuels*.

[23] The public electricity and heat production category includes emissions from utilities and industrial generation.

In 2003, the dominant proportion of GHG emissions, just under 77%, was from the use of coal, while natural gas and oil accounted for just under 13% and 8%, respectively (Table 2-2). In 1990, just over 83% of GHG emissions were from coal, 12% were from oil, and 4% were from natural gas. In 1990, emissions from other electricity sources made up just under 0.5% of public electricity emissions, whereas in 2003, the same sources accounted for almost 3% of the subsector's emissions.

TABLE 2-2: GHG Emissions from Electricity Generation, 1990–2003

	(Mt)				
GHG Source Category	**1990**	**1995**	**2000**	**2002**	**2003**
Coal[1]	78.8	83.1	105	102	101
Oil	11.4	6.99	8.77	8.52	10.2
Natural Gas	4.05	9.15	16.1	15.6	16.9

Note:

1 Includes coal products.

Coal has the highest GHG intensity of all fuels — this is reflected in the fact that it accounted for only 19% of the total electricity generated in Canada in 2003 and produced 77% of GHG emissions from that subsector, whereas natural gas accounted for 13% of emissions from electricity generation but generated 6% of Canada's electricity. However, the intensity of coal is improving; in 1990, coal generation accounted for 83% of the emissions and 16% of the electricity. To be more explicit, the intensity factor for coal generation has improved from 1026 g CO_2 eq/kWh in 1990 to 963 g CO_2 eq/kWh in 2003. The intensity factor for natural gas generation was 503 g CO_2 eq/kWh in 2003.

The growth in emissions from 1990 to 2003 is directly related to rising demand for power from end users and the increasing use of fossil fuels in the generation mix. While increasing use of natural gas has helped mitigate the rate of emissions growth, the shift away from non-GHG-emitting sources (nuclear and hydro) in the latter part of the decade has resulted in large absolute increases.

Contributions from both nuclear and hydro generation declined in the latter part of the 1990s, when nuclear facilities in Ontario were decommissioned for maintenance and rehabilitation. Since then, some nuclear generation was brought back into service in Ontario, and new hydroelectric capacity has been added throughout the country. Between 1998 and 2003, there was a 4.2% increase in the amount of electricity from nuclear generation (refer to the electricity tables in Annex 9 for more details). Hydroelectric generation increased nearly 14% from 1990 to 2003; however, production was hampered by low water reservoirs in 2003. In August 2003, Ontario was hit by the blackout that affected Ontario and eight American states. For a week after the blackout, certain parts of Ontario were affected by rolling blackouts until full power was restored. Furthermore, there was an increase in demand for electricity due to colder than normal weather at the end of the 2003 heating season.

While imports rose and fell to meet the supply/demand gap, since 1990, growth in demand was largely met by domestic generation from fossil fuels, primarily coal and natural gas. Coal-fired generation increased 37%, while natural gas generation increased 273% between 1990 and 2003. The growth in natural gas generation is also based on a structural shift towards more efficient industrial cogeneration sources.

- **Petroleum Refining and Manufacture of Solid Fuels and Other Energy Industries[24] (2003 GHG emissions, 71 Mt)**

The petroleum refining category includes emissions from the combustion of fossil fuels during the production of refined petroleum products. The manufacture of solid fuels and other energy industries category encompasses fuel combustion emissions associated with the upstream oil and gas industry (including upgrading of bitumen to synthetic crude oil). As shown in Table 2-3, between 1990 and 2003, emissions from these two subsectors increased by about 20 Mt, just under 39%. This growth is due to increases in oil and natural gas production, largely for export.

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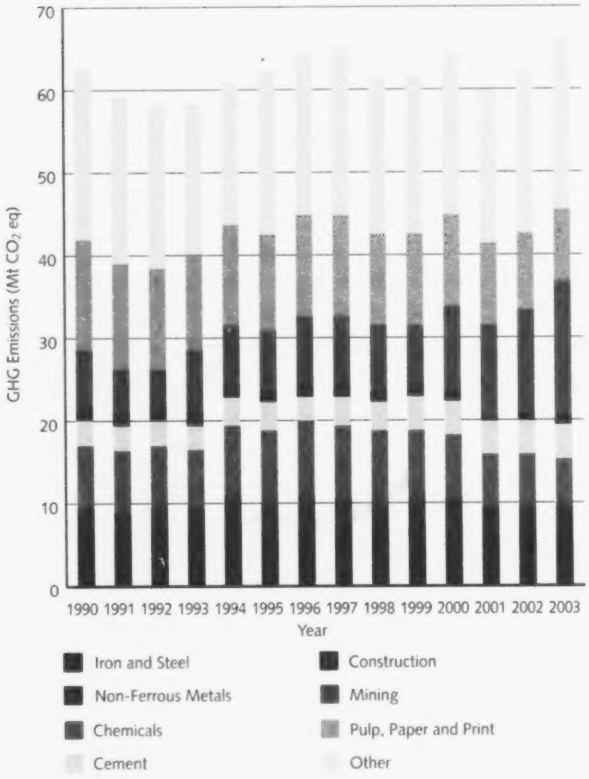
[24] In the NIR, the Fossil Fuel Industries category encompasses both the *petroleum refining* and *manufacture of solid fuels and other energy industries* subsectors.

TABLE 2-3: GHG Emissions from Petroleum Refining and Manufacture of Solid Fuels and Other Energy Industries, 1990–2003

GHG Source Category	1990 (Mt)	1995 (Mt)	2000 (Mt)	2002 (Mt)	2003 (Mt)	% Increase 1990–2003
Petroleum Refining	26	28	28	34	34	30
Manufacture of Solid Fuels and Other Energy Industries	25	26	39	39	38	48
TOTAL	**52**	**55**	**67**	**73**	**71**	**39**

FIGURE 2-2: GHG Emissions from Manufacturing, Mining, and Construction by Subcategory, 1990–2003



Manufacturing, Mining, and Construction Industries (2003 GHG emissions, 66.2 Mt)

Emissions from the manufacturing industries and construction subsector include the combustion of fossil fuels by all manufacturing industries, the construction industry, and mining.[25] In 2003, GHG emissions were 66.2 Mt, an increase of 5.1% from the 1990 level of 63.0 Mt; over the short term (2002–2003), emissions increased by 6.5%. Overall, this subsector was responsible for 8.9% of Canada's total GHG emissions for 2003. Figure 2-2 provides an overview of the changes in emissions for the various manufacturing industries and construction between 1990 and 2003. The amount of emissions in each category can be found in Table 2-4.

Between 1990 and 2003, there have been changes in the emissions produced by the various categories within the manufacturing industries and construction subsector. This can be attributed to product demands, fuel switching, and changes in manufacturing operations. Part of the overall increase can be attributed to the mining category, which has seen a 153% growth, in part due to oil sand (unconventional bitumen) mining activities. In 2003, the construction industry experienced a 5.0% increase in emissions along with a 6.5% increase in housing starts as compared with 2002.

TABLE 2-4: GHG Emissions from Manufacturing, Mining, and Construction, 1990–2003

GHG Source Category	1990 (Mt)	1995 (Mt)	2000 (Mt)	2002 (Mt)	2003 (Mt)	% Increase 1990–2003
Iron & Steel	6.49	7.04	7.19	6.49	6.42	-1
Non-Ferrous Metals	3.23	3.11	3.19	3.22	3.20	-0.7
Chemicals	7.10	8.46	7.86	6.13	5.74	-19
Cement	3.59	3.42	3.97	4.18	4.20	17
Construction	1.88	1.18	1.08	1.24	1.30	-31
Mining	6.20	7.86	10.4	11.8	15.7	153
Pulp, Paper & Print	13.6	11.7	11.0	9.21	9.13	-33
Other Manufacturing	20.9	19.4	20.0	19.9	20.5	-1.6
TOTAL	**63.0**	**62.1**	**64.6**	**62.2**	**66.2**	**5.1**

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[25] The NIR categories that constitute this UNFCCC sector are *manufacturing*, *construction*, and *mining* (refer to Tables S-1 and S-2).

Transport (2003 GHG emissions, 190 Mt)

Transport is a large and diverse subsector, accounting for 25% of Canada's GHG emissions in 2003. This subsector includes emissions from fuel combustion for the transport of passengers and freight in six distinct subcategories:

- road transport;
- aviation;
- marine;
- rail;
- off-road ground transport (e.g., construction or agriculture vehicles); and
- pipelines (both oil and gas; represent non-vehicular transport).

From 1990 to 2003, GHG emissions from transport, driven primarily by energy used for personal transportation, rose 26%, or almost 40 Mt. Overall, transport was the second leading emissions-producing category in 2003, contributing 190 Mt and accounting for over 27% of Canada's emissions growth from 1990 to 2003.

Emissions from LDGTs, the subcategory that includes SUVs and vans, increased 93% between 1990 and 2003 (from 22 Mt in 1990 to 42 Mt in 2003), while emissions from cars (LDGVs) decreased 8.3% (from 54 Mt in 1990 to 49 Mt in 2003) (Table 2-5).

The growth in road transport emissions may be due not only to the 23% increase in the total vehicle fleet, but also to a shift in light-duty vehicle purchases from cars (LDGVs) to trucks (LDGTs), which, on average, emit 40% more GHGs per kilometre.

Over the period 1990–2003, the increase of 20 Mt and 17 Mt for LDGTs and HDDVs, respectively, indicates the trend towards increasing use of SUVs for personal transportation and heavy-duty trucks for freight transport (Table 2-6).

In 2003, emissions from HDDVs contributed 42 Mt to Canada's total GHG emissions (an increase of 71% from 1990 emissions). Emissions from heavy-duty gasoline vehicles (HDGVs) were substantially lower, at 4 Mt for 2003, but this figure represents an increase of 32% over the 1990 level. While there are difficulties in obtaining accurate and complete data for the freight transport mode, the trends in data from major for-hire truck haulers in Canada show conclusively that freight hauling by truck has increased substantially and that this activity is the primary task performed by HDGVs and HDDVs.

Off-road fuel combustion emissions[26] in the Transport subsector also increased between 1990 and 2003. Emissions from off-road vehicles (snowmobiles, all-terrain vehicles, excavating, construction, etc.) rose 18%.

TABLE 2-5: GHG Emissions from Transport, 1990–2003

Mt CO_2 eq

GHG Source Category	1990	2002	2003
Transport TOTAL	**150**	**180**	**190**
Domestic Aviation	6.4	6.8	7.2
Light-Duty Gasoline Vehicles	53.8	49.7	49.3
Light-Duty Gasoline Trucks	21.7	40.7	41.9
Heavy-Duty Gasoline Vehicles	3.14	4.14	4.14
Motorcycles	0.23	0.23	0.23
Light-Duty Diesel Vehicles	0.67	0.68	0.72
Light-Duty Diesel Trucks	0.59	0.76	0.79
Heavy-Duty Diesel Vehicles	24.5	39.6	42.0
Propane & Natural Gas Vehicles	2.2	0.85	0.81
Railways	7	6	6
Domestic Marine	5.0	5.5	6.1
Off-Road Gasoline	5	4	4
Off-Road Diesel	10	10	20
Pipelines	6.90	10.9	9.11

Note:
For full details of all years, please refer to Annex 8.

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[26] Off-road emissions include those from the combustion of diesel and gasoline in a variety of widely divergent activities. Examples include the use of heavy mobile equipment in the construction, mining, and logging sectors, recreational vehicles such as snowmobiles, and lawn and garden devices such as lawnmowers and trimmers.

TABLE 2-6: **Trends in Vehicle Populations for Canada, 1990–2003**

Number of vehicles (all figures in 000s)

Year	LDGVs	LDGTs	HDGVs	MCs	LDDVs	LDDTs	HDDVs	Total
1990	11 068	3 453	217	331	124	74	350	**15 616**
1991	11 033	3 650	234	324	120	73	398	**15 833**
1992	10 981	3 843	252	313	116	72	445	**16 022**
1993	10 942	4 039	269	309	112	71	493	**16 235**
1994	10 904	4 236	287	304	109	70	541	**16 451**
1995	10 864	4 432	305	295	105	69	589	**16 658**
1996	10 678	4 712	322	288	106	68	637	**16 811**
1997	10 665	4 980	321	299	105	78	641	**17 088**
1998	10 680	5 134	347	314	104	73	633	**17 285**
1999	10 809	5 810	272	315	105	79	658	**18 047**
2000	10 603	6 026	288	326	105	107	704	**18 159**
2001	10 877	6 286	270	330	112	113	712	**18 700**
2002	10 867	6 480	269	307	117	122	704	**18 866**
2003	10 875	6 720	269	306	124	125	731	**19 150**

Notes:

LDGVs: Light-Duty Gasoline Vehicles
LDGTs: Light-Duty Gasoline Trucks
HDGVs: Heavy-Duty Gasoline Vehicles
MCs: Motorcycles
LDDVs: Light-Duty Diesel Vehicles
LDDTs: Light-Duty Diesel Trucks
HDDVs: Heavy-Duty Diesel Vehicles

The pipeline emissions included in the Transport subsector are combustion emissions primarily from natural gas transport. Due to increasing activity in the Energy Sector, these emissions rose 32%, from 6.9 Mt in 1990 to 9.1 Mt in 2003.

Other Sectors (2003 GHG emissions, 87 Mt)

The Other Sectors category comprises fuel combustion emissions from the residential and commercial subsectors, as well as stationary fuel combustion emissions from both the agriculture and forestry categories.[27] Overall, this category exhibited increases in GHG emissions of 20% from 1990 to 2003, while individual subcategories within it demonstrated a variety of changes.

■ Residential and Commercial

Emissions in these categories arise primarily from the combustion of fuel to heat residential and commercial buildings. Fuel combustion in the residential and commercial/institutional categories[28] accounted for 6.1% (45 Mt) and 5.3% (39 Mt), respectively, of all GHG emissions in 2003.

As shown in Figure 2-3, residential emissions have remained fairly constant between 1990 and 2003, increasing 1.3 Mt over this period. In the short term, emissions increased by 1.8 Mt or 4.2% between 2002 and 2003. Commercial/institutional emissions increased 13.1 Mt or 51% between 1990 and 2003. The combined effect between 1990 and 2003 for the two categories was an increase of 15 Mt, or 21%. GHG emissions, particularly in the residential category, track HDDs[29] closely (as shown in Figure 2-3). This close tracking indicates the important influence of weather on space heating requirements and therefore on the demands for natural gas, home heating oil, and biomass fuels.

Floor space in both the residential and commercial subsectors increased significantly and consistently in the same period. In 2003, housing starts were up 6.5% over 2002 starts. In the commercial subsector, there has been a change in the mix of building types, with a reduction in warehouse-type buildings and an increase in office floor space. The increase in office floor space has led to an increased demand for space cooling and heating. There has also been an increase in the number of appliances in homes and auxiliary equipment in offices (NRCan, 2004). This upward trend in floor space and equipment was counteracted by the following influences: fuel substitution away from petroleum products, improvements in end-use efficiency, and improvements in the thermal envelope of houses. In 2003, the use of petroleum products (such as home heating oil) for space heating accounted for about 15% of the total fuel consumed, while natural gas

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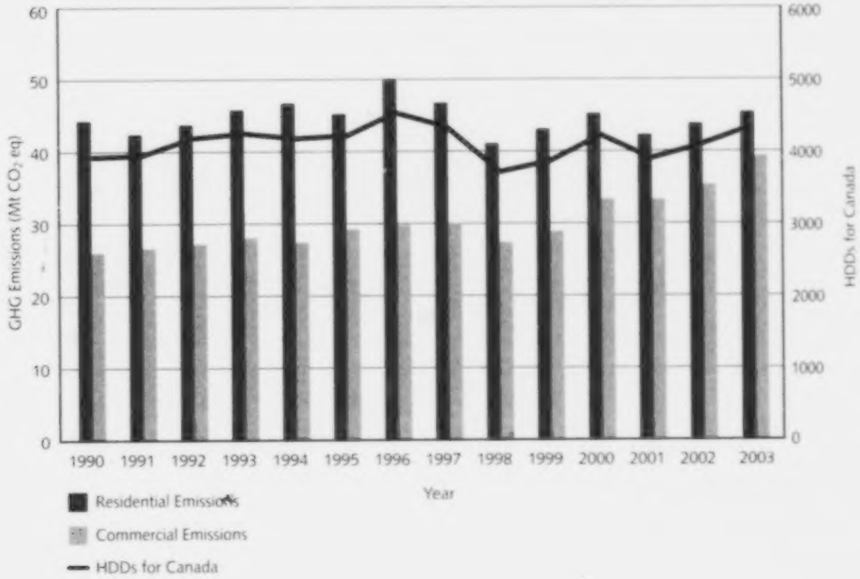
[27] The UNFCCC Other Sectors category comprises the following NIR sectors: *residential, commercial and institutional*, and *other* (listed under energy, fuel combustion in Annex 8).

[28] Commercial sector emissions are based on fuel use as reported in the *Report on Energy Supply–Demand in Canada* (Statistics Canada, 2004) for commercial and other institutional and public administration categories. The former is a catch-all category that includes fuel used by service industries related to mining, wholesale and retail trade, financial and business services, education, health and social services, and other industries that are not explicitly included elsewhere.

[29] HDDs are calculated by determining the average, cross-Canada number of days below 18°C and multiplying this value by the corresponding number of degrees below this temperature.

FIGURE 2-3: Emissions in the Residential and Commercial Sectors Relative to HDDs, 1990–2003



use accounted for 73% as compared with 24% for petroleum products and 61% for natural gas use in 1990.

- **Agriculture and Forestry**

Stationary fuel combustion-related emissions from the agriculture and forestry categories amounted to 2.2 Mt in 2003, a decrease of 8.5% since 1990. Emissions increased 5.0% between 2002 and 2003.

2.3.1.2 Fugitive Emissions from Fuels (2003 GHG emissions, 54 Mt)

As stated above, fugitive emissions from fossil fuels are the intentional or unintentional releases of GHGs from the production, processing, transmission, storage, and delivery of fossil fuels. Released gases that are combusted before disposal (e.g., flaring of natural gases at oil and gas production facilities) are also considered fugitive emissions. Fugitive emissions have two sources: coal mining and handling, and activities related to the oil and natural gas industry. They constituted 7.3% of Canada's total GHG emissions for 2003 and contributed 11% to the growth in emissions between 1990 and 2003.

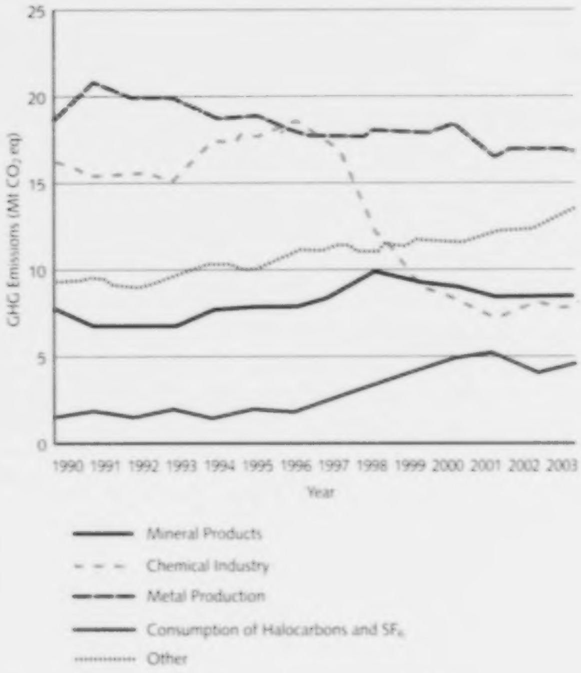
Table 2-1 summarizes the changes in fugitive emissions by the UNFCCC subcategories solid fuels and oil and natural gas. In total, fugitive emissions grew by about 42% between 1990 and 2003, from 38 Mt to 54 Mt, with emissions from the oil and natural gas category contributing 98% of the total fugitive emissions in 2003, far overshadowing the 2% contribution from coal mining. Although fugitive releases from the solid fuels category (i.e., coal mining) decreased by almost 1 Mt (over 48%) between 1990 and 2003 due to the closing of many mines in eastern Canada, emissions from oil and natural gas increased 47% during the same period.

This rise in emissions is a result of the increased production of natural gas and heavy oil since 1990, largely for export to the United States. Since 1990, there has been a 180% increase in the net energy exported from Canada, accompanied by a 115% increase in GHG emissions associated with those net energy exports.

2.3.2 INDUSTRIAL PROCESSES SECTOR (2003 GHG EMISSIONS, 52 Mt)

The Industrial Processes Sector includes GHG emissions that are direct by-products of processes, including mineral production and use, chemical industry, metal production, consumption of halocarbons and SF_6, and other and undifferentiated production. The GHG emissions from the Industrial Processes Sector contributed 52.0 Mt to the 2003 national GHG inventory, as compared with 54.4 Mt in 1990. Figure 2-4 illustrates the changes in each of the categories over the period 1990–2003, and Table 2-7 provides an emission breakdown by category for selected years.

FIGURE 2-4: GHG Emissions from Industrial Processes by Category, 1990–2003



The largest single source of emissions in 2003 was metal production, with almost 17 Mt of emissions, as shown in Table 2-7. The other & undifferentiated production category has accounted for the largest increase in emissions (about 49%) since 1990. These emissions are primarily from non-energy uses of fossil fuels, including the use of natural gas to produce hydrogen in the oil upgrading and refining industries, the use of natural gas liquids (NGLs) as feedstock in the chemical industry, and the use of lubricants.

TABLE 2-7: GHG Emissions from Industrial Processes by Category, 1990–2003

	Mt CO_2 eq				
GHG Source Category	1990	1995	2001	2002	2003
Industrial Processes TOTAL	**54.4**	**57.3**	**50.8**	**51.0**	**52.0**
a. Mineral Production	**7.8**	**8.1**	**8.5**	**8.6**	**8.7**
Cement	5.6	5.9	6.5	6.7	6.8
Lime	2	2	2	2	2
Limestone and Soda Ash Use	0.45	0.36	0.35	0.24	0.24
b. Chemical Industry	**17**	**18**	**7.5**	**8.3**	**8.1**
Ammonia Production	5.0	6.5	5.9	6.2	6.1
Nitric Acid Production	0.78	0.78	0.80	0.81	0.81
Adipic Acid Production	10.7	10.7	0.80	1.25	1.09
c. Metal Production	**19.1**	**19.1**	**16.9**	**17.1**	**16.8**
Iron and Steel Production	7.06	7.88	7.28	7.11	7.04
Aluminium Production	8.93	9.09	7.36	7.11	7.32
SF_6 Used in Magnesium Smelters and Casters	3.11	2.11	2.30	2.91	2.48
d. Consumption of Halocarbons and SF_6	**1.8**	**2.0**	**5.1**	**4.1**	**4.7**
e. Other & Undifferentiated Production	**9.2**	**10.2**	**12.6**	**12.7**	**13.7**

Despite a rising trend from 1990 to 1996, total emissions from the Industrial Processes Sector declined significantly through 1997–2003. Between 1990 and 2003, the overall sector emissions decreased by 2.4 Mt (about 4.4%). These reductions can be explained by the installation of an emission abatement system at Canada's only adipic acid facility since 1997, progressive replacement of SF_6 with alternatives used as cover gas in magnesium production and casting, and incorporation of automated emission controls in aluminium production.

2.3.3 SOLVENT AND OTHER PRODUCT USE SECTOR (2003 GHG EMISSIONS, 0.5 Mt)

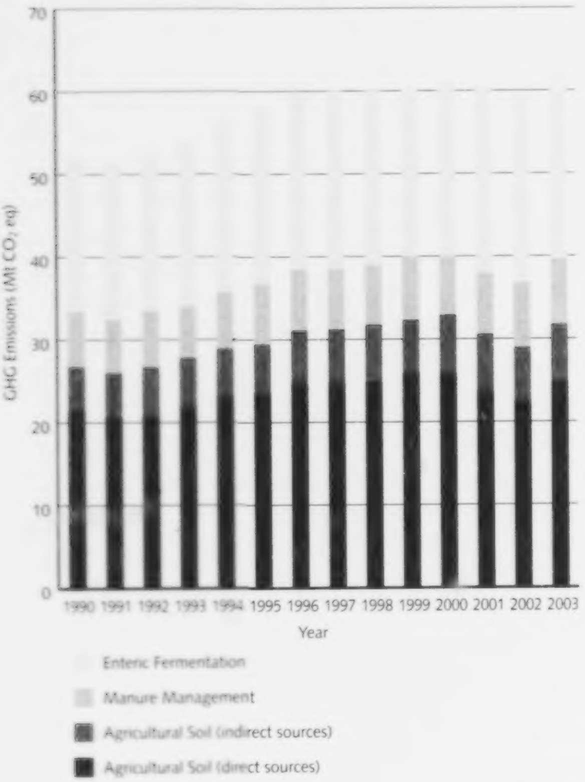
The Solvent and Other Product Use Sector accounts for emissions related to the use of N_2O as an anaesthetic in medical applications and as a propellant in aerosol products. It contributed 480 kt CO_2 eq to the 2003 national GHG inventory, as compared with 420 kt CO_2 eq in 1990. Although the emissions coming from this sector represented less than 1% of the total Canadian GHG emissions in 2003, they were 14% above their 1990 levels.

2.3.4 AGRICULTURE SECTOR (2003 GHG EMISSIONS, 62 Mt)

Canada's Agriculture Sector is composed of approximately 250 000 farms, 98% of which are family owned. Agricultural emissions accounted for 62 Mt or 8.4% of total 2003 GHG emissions for Canada, an increase of 10 Mt since 1990. All of these emissions are from non-energy sources, with N_2O accounting for 58% of sectoral emissions and CH_4 for 42% in 2003.

The processes that produce GHG emissions in the Agriculture Sector are enteric fermentation by domestic animals, manure management, fertilizer application, and crop production.

FIGURE 2-5: **GHG Emissions from Agricultural Sources, 1990–2003**



Emissions in this sector were analyzed based upon the following two main categories:

- Livestock-related emissions due to enteric fermentation from domestic animals (i.e., digestive processes that release CH_4) and manure management (which releases CH_4 and N_2O). These emissions accounted for 49% of total Agriculture Sector GHG emissions in 2003.
- Soil management and cropping practices contribute N_2O emissions due to fertilizer application and legume and non-leguminous crop production. These sources accounted for about 51% of total Agriculture Sector GHG emissions in 2003.

In the 1990–2003 period, enteric emissions increased by 20%, emissions from manure management systems by 18%, and soil N_2O emissions by 19% (Figure 2-5). These increases mainly result from the expansion of the beef cattle, swine, and poultry industry, as well as the increase in consumption of synthetic nitrogen fertilizer.

Between 2002 and 2003, there was a noticeable increase in N_2O emissions from agricultural soils, amounting to 2.6 Mt. The year 2002 had seen a severe drought in most regions of Canada, leading to a lower than average crop production.

Due to changes to the international reporting guidelines, emissions and removals of CO_2 from agricultural soils, which were previously reported under the Agriculture Sector, are now reported in the LULUCF Sector under the "Cropland Remaining Cropland" category (see Chapter 7).

In the 2003 GHG inventory for the Agriculture Sector, a few major changes related to methodologies (IPCC Tier 2 methodologies for enteric fermentation and manure management practices) and updates in animal population data were implemented with the associated recalculations, but these changes did not significantly impact the emission trends.

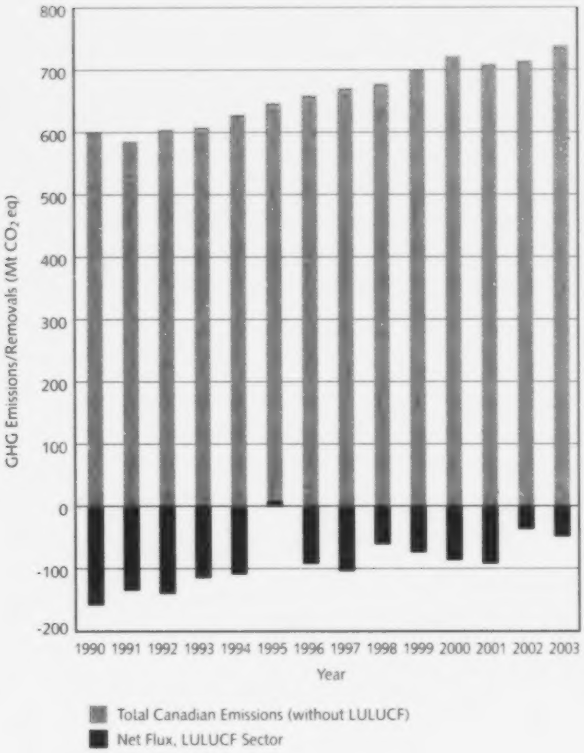
2.3.5 LAND USE, LAND-USE CHANGE AND FORESTRY SECTOR (2003 NET GHG REMOVALS, 44 MT, NOT INCLUDED IN NATIONAL TOTALS)

The LULUCF Sector reports GHG fluxes between the atmosphere and Canada's managed lands, as well as those associated with changes in the way in which land is used. To comply with the new LULUCF reporting format, CO_2 fluxes to and from agricultural soils are now reported in this sector (see below and Chapter 7, "New Reporting Format").

The net LULUCF flux, calculated as the sum of CO_2 emissions and removals and non-CO_2 emissions, displays high interannual variability over the reporting period. In 2003, this net flux amounted to a removal of 44 Mt (Figure 2-6).

Based on Canada's understanding of Decision 13/CP.9 of the ninth Conference of the Parties to the UNFCCC, all emissions and removals in the LULUCF Sector are excluded from the national totals. This differs from previous reports, where non-CO_2 emissions from LULUCF were included in the national totals. In 2003, the estimated 44 Mt would, if included, decrease the total Canadian GHG emissions by 6%.

FIGURE 2-6: Contribution of LULUCF Sector to Canada's GHG Emission Totals, 1990–2003



This year, Canada is implementing, on a trial basis, a new reporting format for the LULUCF Sector that was adopted by the Conference of the Parties to the UNFCCC (Decision 13/CP.9). In this format, GHG emissions from sources and removals by sinks are estimated and reported for five categories:

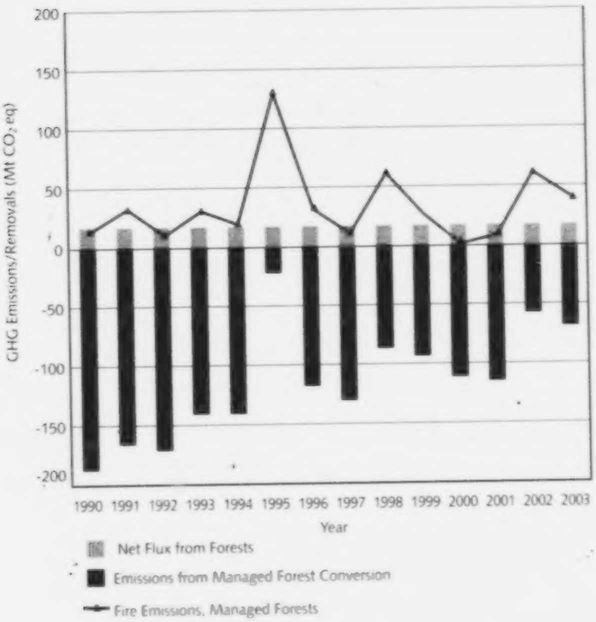
- Forest Land;
- Cropland;
- Grassland;
- Wetlands; and
- Settlements.

The Forest Land category includes GHG emissions to and removals from the aboveground biomass of Canada's managed forests and exerts an overriding influence on the sectoral trend. The net GHG flux reflects the difference between carbon uptake by tree growth and emissions due to disturbances, specifically harvesting activities and wildfires. The high variability in the net flux from the managed forests is associated with the impact of wildfires, which alone accounted for annual emissions between 11 and 130 Mt over the 1990–2003 period (Figure 2-7). Both short- and long-term trends should therefore be interpreted with caution, given that the sector as a whole retains the important inter-annual variability resulting from large fluctuations in the severity of the fire season, with an additional random effect due to the location of fires with respect to the managed forests (as opposed to non-managed). The long-term effect of disturbances has been to reduce the stocked, actively growing area of managed forests from 74% of its total area in 1990 to 65% in 2003, hence contributing to the declining net sink.

Readers should acquaint themselves with the information presented in Chapter 7 and Section A3.2 in Annex 3 of the present report in order to properly interpret these estimates and understand their limitations.

The Cropland subcategory includes the effect of agricultural practices on CO_2 emissions and removals from arable soils and the impact on GHG emissions or removals associated with forest and grassland conversion to cropland. In 2003, arable soils represented a net sink of 1.5 Mt, while land conversion to cropland accounted for emissions of nearly 16 Mt.

FIGURE 2-7: Selected Emissions and Removals in LULUCF Sector, 1990–2003



Note that the net CO$_2$ flux from agricultural soils (1.5 Mt) was formerly reported in the Agriculture Sector of the inventory. The continued adoption of no-till practices and reduction in the frequency of summerfallow explain the steady trend of diminishing CO$_2$ emissions from cropland remaining cropland and the reversal, in 2001, of the net CO$_2$ flux to a removal.

For the time being, estimates reported under the Grassland and Settlements subcategories include only the effect of forest conversion to grassland, urbanization, and the minimal contribution of urban forests. Work is under way to address other reporting requirements (see Section 7.4.6 in Chapter 7).

Preliminary estimates of deforestation in Canada suggest that forest losses to cropland, grassland, and urbanization amount to emissions of about 18 Mt CO$_2$. In general, emissions or removals associated with land conversion are estimated as annual averages over the reporting period and therefore do not display any trend. Again, the reader is referred to more detailed documentation in Chapter 7 and Section A3.2 in Annex 3 of the present report.

As explained in more detail in Chapter 7, Canada is engaged in a multi-year effort to substantially improve its estimates for the LULUCF Sector. The objective is to simultaneously meet the good practice standards elaborated in the recent IPCC report (IPCC, 2003), address major uncertainties, and provide estimates that are a more complete picture of emissions and removals, especially from forest land and cropland. The estimates reported in this submission should be considered transitory, pending consolidation and implementation of the efforts currently under way.

2.3.6 WASTE SECTOR (2003 GHG EMISSIONS, 25 MT)

From 1990 to 2003, GHG emissions from waste increased 27%, surpassing the population growth of 14.2%. By 2003, these emissions represented 3.4% of Canadian GHG emissions. These emissions consist almost entirely of CH$_4$ produced by the decomposition of biomass in municipal solid waste (MSW). In 2003, of the nearly 25 Mt total emissions from this sector, emissions from solid waste disposal on land accounted for 24 Mt, while emissions from municipal wastewater treatment and from incineration of waste (excluding emissions from incineration of biomass material) contributed 1.4 Mt and 0.4 Mt, respectively. The tables in Annex 8 summarize the annual changes in each of the three Waste Sector subcategories between 1990 and 2003.

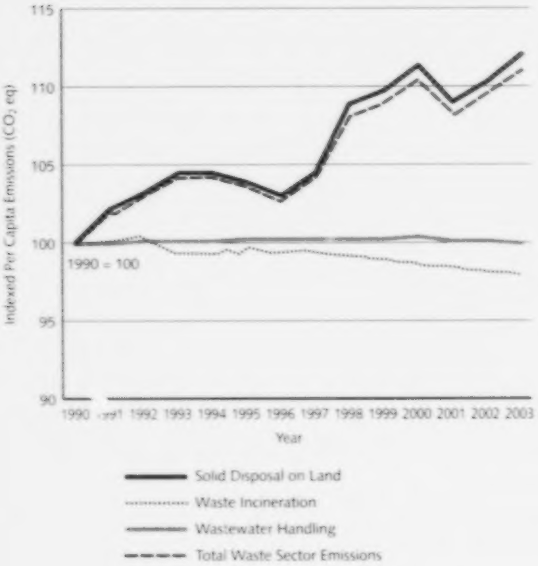
CH$_4$ emissions from MSW landfills increased by nearly 27% between 1990 and 2003, despite an increase in landfill gas capture and combustion of almost 48% over the same period. In 2003, approximately 310 kt of CH$_4$ (or 6600 kt CO$_2$ eq) were captured by the 44 landfill gas collection systems operating in Canada (Environment Canada, 2003). Of the total amount of CH$_4$ collected, 55%, or 170 kt CH$_4$, was utilized for various energy purposes at 16 sites, and the remaining 45%, or 140 kt CH$_4$, was flared at 28 sites.

GHG emissions from landfills are tabulated for two types of waste, MSW and wood waste landfills, both of which produce CH_4 anaerobically.[30] The CH_4 production rate at landfills is a function of several factors, including the mass and composition of biomass being landfilled, the landfill temperature, and the moisture entering the site from rainfall.

Per capita emissions from this sector increased 11% from 1990 to 2003, due primarily to the increasing emissions from landfills (Figure 2-8). CH_4 capture programs at landfills have made significant contributions to reductions in emissions during this period. Trend growth exceeds population increases, since material landfilled in past decades is still contributing to CH_4 production. The decline in per capita growth observed in the mid-1990s, shown in Figure 2-8, is directly attributable to CH_4 capture programs at landfills.

Emissions from wastewater handling have remained fairly constant, while waste incineration has shown a small decrease in GHG emissions over the 1990–2003 period.

FIGURE 2-8: **Per Capita GHG Emission Trend for Waste, 1990–2003**



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[30] When waste consists of biomass, the CO_2 produced from burning or aerobic decomposition is not accounted for in the Waste Sector, as it is deemed a sustainable cycle (carbon in CO_2 will be sequestered when the biomass regenerates). In theory, emissions of CO_2 are accounted for as part of the LULUCF Sector; however, waste that decomposes anaerobically produces CH_4, which is not used photosynthetically and therefore does not sequester carbon in biomass. The production and release of unburned CH_4 from waste are therefore accounted for in GHG inventories.

3 ENERGY (CRF SECTOR 1)

3.1 FUEL COMBUSTION (CRF CATEGORY 1.A)

The fuel combustion category includes all emissions from fuel combustion activities. Major source categories include Energy Industries, Manufacturing and Construction, Transport, and Other Sectors (residential, commercial, etc.). The general methods used to calculate emissions from fuel combustion are consistent throughout and are presented in Annex 2: Methodology and Data for Estimating Emissions from Fuel Combustion.

In 2003, 546 Mt (or 74%) of Canada's GHG emissions were from the combustion of fossil fuels (Table 3-1). The overall GHG emissions from fuel combustion activities increased by 27% since 1990 and by 3.3% since 2002. Between 1990 and 2003, emissions from the Energy Industries (combustion) and from the Transport category increased by about 40% and 26%, respectively.

TABLE 3-1: Fuel Combustion GHG Contribution

GHG Source Category	1990	kt CO_2 eq 2002	2003
Fuel Combustion TOTAL	**431 000**	**529 000**	**546 000**
Energy Industries	147 000	202 000	206 000
Manufacturing and Construction	63 000	62 200	66 200
Transport	150 000	180 000	190 000
Other Sectors	72 000	81 000	87 000

3.1.1 ENERGY INDUSTRIES (CRF CATEGORY 1.A.1)

3.1.1.1 Source Category Description

This category includes all emissions from stationary fuel combustion sources in the production, processing, and refining of energy. The category is subdivided into subcategories of Public Electricity and Heat Production, Petroleum Refining, and Manufacture of Solid Fuels and Other Energy Industries (which consists primarily of oil and natural gas production).

Although actually associated with the Energy Industries, emissions from venting and flaring activities related to the production, processing, and refining of fossil fuels are reported as fugitive emissions.

In 2003, the Energy Industries (combustion) category accounted for 206 Mt (or about 28%) of Canada's total GHG emissions, with an overall increase of 40% since 1990. Over 65% (or 134 Mt) of the GHG emissions are from Public Electricity and Heat Production, while the Petroleum Refining and the Manufacture of Solid Fuels and Other Energy Industries contributed 16% (34 Mt) and 18% (38 Mt), respectively (Table 3-2). Additional Energy Industries' trend discussions are available in the Emission Trends chapter (Chapter 2) and in the industrial analysis annex (Annex 10).

TABLE 3-2: Energy Industries GHG Contribution

GHG Source Category	1990	kt CO_2 eq 2002	2003
Energy Industries TOTAL	**147 000**	**202 000**	**206 000**
Public Electricity and Heat Production	95 300	129 000	134 000
Petroleum Refining	26 000	34 000	34 000
Manufacture of Solid Fuels and Other Energy Industries	25 000	39 000	38 000

Public Electricity and Heat Production (CRF Category 1.A.1.a)

The electric supply grid in Canada includes thermal combustion-derived electricity as well as hydro, nuclear, wind, and tidal power. The total power generated from wind, tidal, and solar power is relatively small. Nuclear, hydro, wind, solar, and tidal power generation are not direct emitters of GHGs. Therefore, emission estimates are made only for thermal combustion-derived electricity.

Two systems are used to generate electricity using thermal combustion:

- steam generation; and
- internal combustion (turbine and reciprocating) engines.

Steam turbine boilers are fired with coal, heavy fuel oil, natural gas, or biomass. For steam turbines, the initial heat may be produced using light fuel oil, natural gas, kerosene, or diesel oil. Reciprocating engines use light oil, diesel, natural gas, and/or a combination of all of these. Gas turbines are fired with natural gas or refined petroleum products.

Petroleum Refining (CRF Category 1.A.1.b)

Crude oil is refined by distillation and other processes into petroleum products, such as gasoline and diesel oil. The heat required for these processes is generated by combusting either internally generated fuels (e.g., refinery fuel gas) or purchased fuels (e.g., natural gas). CO_2 is also generated as a by-product during the production of hydrogen (steam reforming of natural gas). These are process-related emissions and reported accordingly under the Industrial Processes Sector (see Chapter 4).

Manufacture of Solid Fuels and Other Energy Industries (CRF Category 1.A.1.c)

This sector comprises fuel combustion emissions associated with the upstream oil and gas industry (not including pipeline transmission systems) and coal mining. Emissions associated with pipeline transmission are reported under Transportation – Others.

3.1.1.2 Methodological Issues

Emissions for all subsectors are calculated following the methodology described in Annex 2 and are based on national fuel consumption statistics reported in the *Report on Energy Supply–Demand in Canada* (RESD) (Statistics Canada, #57-003). The method is consistent with an IPCC Tier 2 method.

Public Electricity and Heat Production (CRF Category 1.A.1.a)

Emissions for this category are calculated using all fuel use (including diesel and any gasoline) reported for both industrial and utility electricity generation and steam generation (reported as fuel transformation) in the RESD.

IPCC inventory guidelines (IPCC/OECD/IEA, 1997) require the Public Electricity and Heat Production sector to include only emissions generated by public utilities. Emissions associated with industrial generation should be allocated to the industry category that produces the energy under the appropriate industrial sector in the Energy Sector, regardless of whether the energy is for sale or for internal use. The rationale for this is that the IPCC recognizes that it is difficult to disaggregate emissions in cogeneration facilities (i.e., to separate the electricity component from the heat component of fuel use). Statistics Canada fuel-use data in the RESD do distinguish industrial electricity generation data and aggregate the data into one category titled industrial electricity generation. As a result, the GHG inventory does not allocate industrial electricity generation emissions to specific industrial subsectors; rather, these emissions are lumped together and reported with public electricity and heat generation.

Petroleum Refining (CRF Category 1.A.1.b)

Emissions for this category are calculated using all fuel use attributed to the petroleum refining industry in the RESD. This includes all petroleum products (including still gas, petroleum coke, diesel, etc.) reported as producer consumption and purchases of natural gas for fuel use by refineries. Included in this category are emissions from the use of internally generated fuels in oil sand mining and upgrading operations.

Manufacture of Solid Fuels and Other Energy Industries (CRF Category 1.A.1.c)

Emissions for this category are calculated using natural gas, NGLs, and coal fuel-use data reported for fossil fuel producers, titled *producer consumption*, in the RESD. The fuel-use data in the RESD include volumes of flared fuels; however, flaring emissions are calculated and reported separately in the fugitive category. The fuel use associated with flaring emissions is subtracted from the data derived from the RESD to avoid double-counting of emissions. Any emissions resulting from commercial fuel purchases by the petroleum production and coal mining industries are reported with the mining sector (Section 3.1.2).

3.1.1.3 Uncertainties and Time-Series Consistency

The estimated uncertainty for the Energy Industries category ranges from -4% to 6% for all gases and from -6% to 2% for CO_2 alone. Refer to the Uncertainty annex (Annex 7) for additional discussion on the ICF (2004) uncertainty study and additional uncertainty values for the Energy Industries category.

The uncertainties for the Energy Industries category are largely dependent on the collection procedures used for the underlying activity data as well as on the representativeness of the emission factors for specific fuel properties. Commercial fuel volumes and properties are generally well-known, while there is greater uncertainty surrounding both the reported quantities and properties of non-market fuels (such as field uses of natural gas and refinery fuel gas). For example, in the Petroleum Refining subcategory, the CO_2 emission factors for non-market fuels as consumed, such as refinery still gas, petroleum coke, and catalytic coke, have a greater influence on the uncertainty estimate than the CO_2 factors for commercial fuels.

For the Public Electricity and Heat Production category, the uncertainty associated with industrial electricity generation is higher than utility-generated electricity due to lack of disaggregated information.

Over 98% of the 2003 emissions from the Manufacture of Solid Fuels and Other Energy Industries category are associated with natural gas production and processing. The uncertainty for this category is influenced by the CO_2 emission factors (±6%) and CH_4 emission factors (0% to 240%) for the consumption of unprocessed natural gas. A national weighted emission factor was used to estimate emissions for the natural gas industry due to a lack of plant-level information, such as the physical composition of unprocessed natural gas (which will vary from plant to plant). Thus, the overall uncertainty estimate is based on a rather broad assumption as well.

The estimated uncertainty for CH_4 (1% to 230%) and N_2O emissions (-23% to 800%) for the Energy Industries sector is influenced by the uncertainty associated with the emission factors. Additional expert elicitation is required to improve the CH_4 and N_2O uncertainty estimates for some of the emission factor uncertainty ranges and probability density functions developed by the ICF (2004) study, since insufficient time was available to have these assumptions reviewed by industry experts.

The estimates for the Energy Industries category are consistent over time and calculated using the same methodology.

3.1.1.4 QA/QC and Verification

Tier 1 QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) were performed on the CO_2 estimates for the following key source subcategories:

- Public Electricity and Heat Production;
- Petroleum Refining; and
- Manufacture of Solid Fuels and Other Energy Industries.

QC checks were done in a form consistent with IPCC Good Practice Guidance (IPCC, 2000). Some elements of a Tier 1 QC check include a review of the estimation model, activity data, emission factors, time-series consistency, transcription errors, reference material, conversion factors, and units labelling, as well as sample emission calculations.

No significant mathematical errors were found during the QC checks; however, a number of labelling and referencing problems were revealed. Updates to the spreadsheets and model, to correct these issues, will assist in producing accurate and error-free future inventories. The data, methodologies, and changes related to the QC activities are documented and archived in both paper and electronic form.

3.1.1.5 Recalculations

The underlying fuel-use data were updated by Statistics Canada and revised for the year 2002, and estimates were recalculated accordingly.

Coal emission estimates for the Energy Industries sector were recalculated to address the step change in emissions between 1994 and 1995. An interpolation method was used to derive coal-specific emission factors for the complete time series based on results from the 2000 fossil fuel emission factor study.

3.1.1.6 Planned Improvements

Three comprehensive petroleum production industry studies were initiated in 2003 and 2004 to assist with the refinement of the inventory estimation model for the oil and gas industry. The objective of these studies is to apply the IPCC Tier 3 and the Good Practice Guidance approach in the development of a detailed GHG inventory for the petroleum production and refining industry.

The Canadian Association of Petroleum Producers (CAPP) and their members are working jointly with NRCan and Environment Canada on the Upstream Oil and Gas Study and on the Canadian Bitumen Industry (unconventional bitumen production) Study to compile a comprehensive inventory of GHG emissions from all sources (i.e., combustion, processes, and fugitive sources) for the 2000 inventory year.

The Canadian Bitumen Industry Study is expected to be completed in 2005. Results from the study will be reviewed by CAPP members, NRCan, and Environment Canada. When finalized, the results of the report will assist with the refinement of the current emission estimation method for the unconventional bitumen industry.

The Upstream Oil and Gas Study was completed in late 2004. An uncertainty estimate was prepared for the 2000 inventory data, and results were also reviewed by CAPP members. As part of the improvement plan to further refine the accuracy of the national inventory's upstream oil and gas model for future UNFCCC submissions, CAPP and Environment Canada have initiated the development of a recalculation model, based on results, to develop estimates beyond 2000.

NRCan, Environment Canada, and the Canadian Petroleum Products Institute (CPPI) have also completed a comprehensive study of GHG emissions for the petroleum refining industry. The next step of the improvement plan is to assess the output of the refinery study and ensure that the information in the report is transparent and complete and can be used to improve the quality and accuracy of the current inventory. Results from the refinery study may also assist in the development of a venting and flaring estimation model.

Future improvement plans also include a study to collect carbon and energy content information on coal to further improve the quality of the emission estimates from the consumption of solid fuels for the complete time series.

3.1.2 MANUFACTURING AND CONSTRUCTION (CRF CATEGORY 1.A.2)

3.1.2.1 Source Category Description

This sector comprises emissions from the combustion of fossil fuels by all mining, manufacturing, and construction industries. The UNFCCC has assigned six subsectors under the manufacturing industries and construction category.

In 2003, the Manufacturing and Construction category accounted for 66 Mt (or 8.9%) of Canada's total GHG emissions, with a 5.1% increase in emissions since 1990 (refer to Table 3-3 for more details). Within Manufacturing and Construction, almost 38 Mt (or 56.6%) of the GHG emissions are from the Others subcategory, followed by the Pulp, Paper and Print, the Iron and Steel, and the Chemicals subcategories, at 9.1 Mt (or 13.8%), 6.4 Mt (or 9.7%), and 5.7 Mt (or 8.7%), respectively.

The Others subcategory is made up of Mining, Other Manufacturing and Construction activities. Emissions from mining activities increased by over 153% between 1990 and 2003 and by 32% between 2002 and 2003. Emission growth from mining activities can be attributed to an increase in unconventional bitumen mining activities.

Emissions from fuel combustion by industries for the generation of electricity or steam for sale are assigned to the Energy Industries sector (under Public Electricity and Heat Production). This allocation is contrary to the recommendations of the IPCC guidelines (IPCC/OECD/IEA, 1997), which state that emissions associated with the production of electricity or heat by industries are to be allocated to the industries generating the emissions. Unfortunately, at present, this is not possible, because fuel-use data at the appropriate level of disaggregation are not available (see Section 3.1.1).

Emissions of CH_4 and N_2O from the combustion of biomass are included in the pulp and paper industrial subsector. CO_2 emissions from biomass combustion are not included in totals but are reported separately in the UNFCCC CRF tables as a memo item.

Emissions generated from the use of fossil fuels as feedstocks or chemical reagents such as for use as metallurgical coke during the reduction of iron ore are reported under the Industrial Processes Sector.

TABLE 3-3: **Manufacturing and Construction GHG Contribution**

GHG Source Category	1990	2002	2003
		kt CO_2 eq	
Manufacturing and Construction TOTAL	**63 000**	**62 200**	**66 200**
Iron and Steel	6 490	6 490	6 420
Non-Ferrous Metals	3 230	3 220	3 200
Chemicals	7 100	6 130	5 740
Pulp, Paper and Print	13 600	9 210	9 130
Cement	3 590	4 180	4 200
Others (Mining, Other Manufacturing and Construction)	28 900	32 900	37 500

3.1.2.2 Methodological Issues

Fuel combustion emissions for each subsector within the Manufacturing and Construction sector are calculated using the methodology described in Annex 2, which is consistent with an IPCC Tier 2 method. Emissions generated from the use of transportation fuels (e.g., diesel and gasoline) are reported under the Transport category (Section 3.1.3), with the exception of the mining subcategory. Emissions associated with the use of diesel and gasoline for off-road vehicles in this subcategory are accounted for in mining. Methodological issues specific to each manufacturing subsector are identified below.

Iron and Steel (CRF Category 1.A.2.a)

Fuel-use data for this sector were obtained from the RESD (Statistics Canada, #57-003), reported as iron and steel (Standard Industrial Classification [SIC] 291 or North American Industrial Classification System [NAICS] 3311, 3312, and 33151). Emissions associated with the use of metallurgical coke have been allocated to the Industrial Processes Sector, because the coke is assumed to be used as a reagent for the reduction of iron ore in blast furnaces.

Non-Ferrous Metals (CRF Category 1.A.2.b)

All fuel-use data for this sector were obtained from the RESD (Statistics Canada, #57-003), reported as smelting and refining of non-ferrous metals (SIC 295 or NAICS 3313, 3314, and 33152).

Chemicals (CRF Category 1.A.2.c)

All fuel-use data for this sector were obtained from the RESD (Statistics Canada, #57-003), reported as chemicals (SIC 371 and 3721 or NAICS 3251 and 3253). Note that emissions resulting from fuels used as feedstocks are reported under the Industrial Processes Sector.

Pulp, Paper and Print (CRF Category 1.A.2.d)

All fuel-use data for this sector were obtained from the RESD (Statistics Canada, #57-003), reported as pulp and paper (SIC 271 and 2512 or NAICS 322). Included in this category are industrial wood wastes and spent pulping liquors combusted for energy purposes.

Others (Other Manufacturing and Construction) (CRF Category 1.A.2.f)

This category includes the remainder of industrial sector emissions, including construction, cement, mining, food, beverage, and tobacco subsectors. The mining data also include commercial fuels used in the oil and gas production industry.

All fuel-use data for this sector were obtained from the RESD (Statistics Canada, #57-003), as reported under cement, construction, mining, and other manufacturing (SIC 352, 071 10–39, and 401–429 or NAICS 311–321, 325, 3252, 3254–3259, 326, 327, excluding 32731, and 332–339). The use of diesel and gasoline fuels for the mining subsector is also included and was obtained from the RESD.

3.1.2.3 Uncertainties and Time-Series Consistency

The estimated uncertainty for the Manufacturing and Construction category ranges from -3% to 6% for all gases and from -3% to 2% for CO_2. Refer to the Uncertainty annex (Annex 7) for a detailed discussion on the ICF (2004) uncertainty study and additional uncertainty values for the Manufacturing and Construction category.

The underlying fuel quantities and CO_2 emission factors have low uncertainty because they are predominantly commercial fuels, which have consistent properties and accurate quantity tracking.

As stated under the Energy Industries category, additional expert elicitation is required to improve the CH_4 and N_2O uncertainty estimates for some of the emission factor uncertainty ranges and probability density functions developed by the ICF (2004) study, since these assumptions were not reviewed by industry experts, due to the lack of available time in the study's preparation.

The estimates for the Manufacturing and Construction category have been prepared in a consistent manner over time using the same methodology.

3.1.2.4 QA/QC and Verification

The underlying energy data are reported to the statistics agency (Statistics Canada) in two streams: one from distributors of fuels and the other from actual users of fuel through a fuel-use consumption survey. The two data sets are compared and reconciled by Statistics Canada as a QC measure. Furthermore, a university research centre (Canadian Industrial Energy End-Use Data Analysis Centre, or CIEEDAC) calculates and analyzes emissions based on the Industrial Consumption of Energy Survey data from Statistics Canada. These estimates are cross-checked with the inventory and are comparable.

Manufacturing and Construction, identified as a key category, underwent Tier 1-level QC checks as set out in the framework for the QA/QC plan (see details and references in Annex 6) and in a manner consistent with Good Practice Guidance. While no mathematical errors were found during the QC checks, a number of labelling and referencing problems were revealed. Updates to the spreadsheets and model, to correct these issues, will assist in producing accurate and error-free future inventories. The data, methodologies, and changes related to the QC activities are documented and archived in both paper and electronic form.

3.1.2.5 Recalculations

The underlying fuel-use data were revised by Statistics Canada for the year 2002. These estimates were recalculated accordingly.

CH_4 and N_2O emissions from the use of spent pulping liquor were incorrectly reported in the residential subcategory. These estimates are now currently accounted for in the Pulp, Paper and Print subcategory for the complete time series.

3.1.2.6 Planned Improvements

As a continuous improvement activity, Environment Canada and Statistics Canada are working jointly to improve the quality of the national energy balance and to further disaggregate fuel-use information.

3.1.3 TRANSPORT (CRF CATEGORY 1.A.3)

Transport-related emissions account for roughly one-quarter of Canada's total GHG emissions. The greatest emission growth since 1990 (Table 3-4) has been observed in LDGTs and HDDVs; this growth amounts to 93% (20.2 Mt) for light trucks and 71% (17.5 Mt) for heavy-duty vehicles. A long-term decrease in some transport subsectors has also been registered: specifically, reductions in emissions from LDGVs (cars), propane and natural gas vehicles, and off-road gasoline devices, for a combined decrease of 6.5 Mt since 1990. Generally, the Transport sector has increased 26% and coincidentally has contributed an equivalency of 27% to the total overall growth observed in Canada as a whole.

TABLE 3-4: Transport GHG Contribution

			Mt CO_2 eq	
GHG Source Category		**1990**	**2002**	**2003**
Transport TOTAL		**150**	**180**	**190**
a.	Domestic Aviation	6.4	6.8	7.2
b.	Light-Duty Gasoline Vehicles	53.8	49.7	49.3
c.	Light-Duty Gasoline Trucks	21.7	40.7	41.9
d.	Heavy-Duty Gasoline Vehicles	3.14	4.14	4.14
e.	Motorcycles	0.23	0.23	0.23
f.	Light-Duty Diesel Vehicles	0.67	0.68	0.72
g.	Light-Duty Diesel Trucks	0.59	0.76	0.79
h.	Heavy-Duty Diesel Vehicles	24.5	39.6	42.0
i.	Propane & Natural Gas Vehicles	2.2	0.85	0.81
j.	Railways	7	6	6
k.	Domestic Marine	5.0	5.5	6.1
l.	Off-Road Gasoline	5	4	4
m.	Off-Road Diesel	10	10	20
n.	Pipelines	6.90	10.9	9.11

3.1.3.1 Source Category Description

This sector comprises the combustion of fuel by all forms of transportation in Canada. The sector has been divided into five distinct subsectors:

- Civil Aviation;
- Road Transport;
- Railways;
- Navigation; and
- Other: Transport.

3.1.3.2 Methodological Issues

Fuel combustion emissions associated with the Transport sector are calculated using various adaptations of Equation A1-1 in Annex 1. However, because of the many different types of vehicles, activities, and fuels, the emission factors are numerous and complex. In order to cope with the complexity, transport emissions are calculated using Canada's Mobile Greenhouse Gas Emission Model (MGEM 05). This model incorporates a version of the IPCC-recommended methodology for vehicle modelling (IPCC/OECD/IEA, 1997) and is used to calculate all transport emissions with the exception of those associated with pipelines (energy necessary to propel oil or natural gas) and aviation. The model is primarily used to further disaggregate on-road total fuel volume (RESD) to one of 23 subcategories (bins) per province/territory.

For on-road total fuel volume, MGEM 05 uses a vehicle population profile, fuel consumption ratios (FCRs), emission control technology penetration rates, and estimated vehicle kilometres travelled (Vkmt's) per "bin" to estimate its necessary fuel and adjusts Vkmt's to solve the equation (i.e., balancing the total fuel consumption reported for the transport sector with the fuel consumption calculated for each "bin"). The volume allocated to each of these "bins" will represent the estimated amount of fuel consumed by vehicles of similar emission characteristics determined as a function of their model year, fuel, and vehicle type.

Road transport CO_2 emission factors are fuel dependent (Jaques, 1992), whereas CH_4 and N_2O emission factors are highly dependent upon the specific pollution control devices on each vehicle. Emission factors associated with these gases vary with vehicle type and are listed in Annex 13, Table A13-5.

To calculate final emissions, a specific combination of emission factors (CO_2, CH_4, and N_2O) is multiplied by the total fuel in each of the unique consumption categories mentioned above. CH_4 and N_2O are then adjusted according to their specific GWP to convert their units to CO_2 eq. Emission values are then aggregated to IPCC categories as per their native fuel type and use category.

MGEM was thoroughly updated in 2001 to include new findings on CH_4 and N_2O emissions. Additional data on vehicle populations were also incorporated. Emission factors used by the model have been adopted from many sources; however, emphasis has been on North American research and Canadian studies, in particular. Specific references are included in Annex 13, Table A13-5.

For the 2003 inventory year, a database model (MGEM 05) that addresses all years' emissions simultaneously was constructed to facilitate improvements in subsequent reporting years. This model emulates the operations of the previous spreadsheet-based MGEM (Jaques et al., 1997; Neitzert, 1998) but allows an increased ability to modify relationships as knowledge of historic assumptions evolve.

Civil Aviation (CRF Category 1.A.3.a)

This subsector includes all emissions from domestic air transport (commercial, private, military, agricultural, etc.). Although the IPCC guidelines (IPCC/OECD/IEA, 1997) call for military air transportation emissions to be reported elsewhere, they have been included here. Excluded are emissions from fuel used at airports for ground transport (reported under other transport, off-road) and fuel used in stationary combustion applications at airports. Emissions arising from fuel sold to foreign airlines and fuel sold to domestic carriers but utilized for international flights are considered to be international bunkers and are reported separately.

Methodologies follow a modified IPCC Tier 1 sectoral approach. Emission estimates are calculated based upon the quantities of aircraft fuels consumed (IPCC/OECD/IEA, 1997). Fuel consumption data from the RESD (Statistics Canada, #57-003), reported as Canadian airlines, are multiplied by fuel-specific emission factors (see Annex 13). Also included are aviation gasoline and aviation turbo fuels used in the public administration and commercial/institutional categories.

Recently, an alternative method was discovered to help understand the use of fuel sold to domestic airlines that was consumed for international transport (bunker). This method incorporates the use of tonne-kilometre (t-km) activity data reported by Canadian airlines both domestically and abroad and regionally allocates the fuel sold using a comparison of passenger traffic. Data representing both passenger traffic (Statistics Canada, #51-005 & #51-203 — Air Carrier Traffic at Canadian Airports) and freight activity, which includes the weight of passengers (Statistics Canada, #51-206 — Canadian Civil Aviation) are available publicly and illustrate the separation between domestic and international activity. The initial assumption that half (50%) of total international tonne-kilometres flown by Canadian airlines, both domestically and abroad, are done using domestically purchased fuel allows a preliminary set of results. These results were compared with those generated by external fuel consumption models (SAGE – USA and AERO2K – UK), which employ a "Flight Path by Aircraft Type" evaluation. Subsequent operation of the Canadian model with a 69% assumption (versus 50%) minimizes error with respect to the external models and is therefore adopted as a better separation according to the reported flight activity and corroborating models.

Road Transport (CRF Category 1.A.3.b)

Gasoline and Diesel

The methodology used to evaluate road transport GHG emissions follows a detailed IPCC Tier 3 method, as outlined in IPCC/OECD/IEA (1997). MGEM 05 disaggregates vehicle data and calculates emissions of CO_2, CH_4, and N_2O from all mobile sources except aviation. However, the model was developed principally to handle the complex emission calculations for road transport.

MGEM 05 uses a detailed procedure for calculating emissions from road transport. For this subsector, data on fuel consumption, vehicle type, vehicle control technology, technology age, age distribution of the fleet, fuel efficiency, and average distance travelled per year are all considered. Emissions are calculated and assigned in accordance with the IPCC reporting procedure (IPCC/OECD/IEA, 1997).

In order to improve accuracy, it is necessary to subdivide road transport into numerous subsectors, as emissions are related to vehicle type. Light-duty vehicles (LDVs) comprise automobiles and light trucks. The IPCC road transport subsectors are (IPCC/OECD/IEA, 1997):

- *Cars*: Automobiles designated primarily for transport of persons and having a capacity of up to 12 passengers. The gross vehicle weight rating is 3900 kg or less.
- *Light-Duty Trucks*: Vehicles with a gross vehicle weight rating of 3900 kg or less that are designated primarily for transportation of light-weight cargo or that are equipped with special features such as four-wheel drive for off-road operation.
- *Heavy-Duty Trucks and Buses*: Any vehicle rated at more than 3900 kg gross vehicle weight or designed to carry more than 12 persons at a time.
- *Motorcycles*: Any motor vehicle designed to travel with not more than three wheels in contact with the ground and weighing less than 680 kg.

It is important to note that there are no universally accepted names or weight limits for the various road transport subsectors. However, for environmental emission purposes, Canada, the United States, and Mexico use designations that are closely aligned to those employed for use with the U.S. Environmental Protection Agency (EPA) *MOBILE* Emissions Factor Model. While similar to the above, there are slight differences. For example, the gross vehicle weight rating cut-off between light and heavy vehicles is 8500 lbs. or 3855.6 kg. Canada's emission estimates for CO, NMVOCs, and NO_x are calculated using the EPA designations. The EPA designations are:

- Light-Duty Gasoline Vehicles/Automobiles (LDGVs);
- Light-Duty Gasoline Trucks (LDGTs);
- Heavy-Duty Gasoline Vehicles (HDGVs);
- Motorcycles;
- Light-Duty Diesel Vehicles/Automobiles (LDDVs);
- Light-Duty Diesel Trucks (LDDTs); and
- Heavy-Duty Diesel Vehicles (HDDVs).

Both the UNFCCC and the EPA insert fuel-type descriptors (e.g., gasoline, diesel, natural gas, or propane) into their various vehicle subsectors where appropriate. While CO_2 releases from vehicles are not considered to be technology dependent, CH_4 and N_2O emission levels are affected by changes in emission control equipment. For CH_4 emissions, vehicles equipped with more sophisticated controls tend to have lower emission rates. The effect of pollution-limiting equipment on N_2O emissions is a more complex matter. Catalytic converters became the primary means to control hydrocarbon and, subsequently, NO_x emissions from gasoline vehicles in the late 1970s and early 1980s. Oxidation catalysts appeared first, followed later by "three-way catalysts." The earlier generations of three-way catalysts were part of emission control packages that are now labelled Tier 0 controls. Tier 1,[31] more advanced technology, was introduced to LDVs in North America in 1994. To date, however, research indicates that all catalytic control units increase N_2O emissions, compared with uncontrolled vehicles (De Soete, 1989; Barton and Simpson, 1995). After their introduction, Tier 0 catalytic control units were also shown to have deteriorating capacity to effectively reduce N_2O emissions as they aged (De Soete, 1989; Prigent et al., 1991). The full effects of aging were noted to occur after approximately one year of use. Note that the emission factors used for LDVs equipped with "aged" Tier 0 controls are approximately one order of magnitude higher (on a per unit of fuel basis) than those from uncontrolled vehicles (De Soete, 1989; Barton and Simpson, 1995).

- **Natural Gas and Propane**

No breakdown by vehicle classification is utilized for natural gas and propane vehicles; therefore, it was assumed that virtually all such vehicles are light-duty and the vast majority are automobiles.

- **On-Road vs. Off-Road**

The accuracy of the emission calculations depends upon the accuracy of the input data. For the latest inventory, information on the fuel sold for road transport was obtained from data for retail pump sales and sales to commercial fleets found in the RESD (Statistics Canada, #57-003). Statistics Canada also reports transport fuel use in the agricultural, commercial, industrial, and institutional economic sectors, but there is uncertainty as to whether these fuels are used by vehicles on- or off-road. In the RESD, on-road fuel use is a subset of all (non-rail) ground transportation fuel use. The RESD lists data on four fuels for ground transport in Canada — gasoline, diesel fuel oil, natural gas, and propane — and emissions are calculated separately for each fuel.

Emissions are calculated on the basis of Equation 3-1 (as adapted for vehicles):

Equation 3-1:

$$E = EF_{Category} \cdot Fuel_{Category}$$

where:

E = the total emissions in a given vehicle category

$EF_{Category}$ = the emission factor for the category

$Fuel_{Category}$ = the amount of fuel consumed in a given category

Because their emissions and emission factors differ, on-road fuel use must be separated from off-road fuel consumption. For the data from the RESD, the two are related in the following way:

Equation 3-2:

$$Fuel_{Ground\ (non\text{-}rail)} = Fuel_{Road} + Fuel_{Off\text{-}road}$$

where:

$Fuel_{Ground\ (non\text{-}rail)}$ = the total fuel used by all categories of ground transport (except rail), as reported by Statistics Canada

$Fuel_{Road}$ = the quantity of fuel used for on-road transport

$Fuel_{Off\text{-}road}$ = the quantity of fuel used for off-road transport (including agricultural, industrial, and construction vehicles, as well as snowmobiles, recreational vehicles, etc.)

For the purposes of the Transport sector in this inventory, it was assumed that all natural gas and propane are used in on-road transport vehicles only. Although not completely correct, this assumption introduces only a small degree of error and allows a separate, simplified analysis of alternatively fuelled vehicles.

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[31] It is important not to confuse the Tier 0 and Tier 1 vehicle emission control system designators mentioned above with the IPCC use of "tier" to differentiate levels of sophistication for estimating emissions.

On-road consumption of diesel oil and gasoline by vehicle type is directly determined by MGEM 05 from available data. The governing equation is:

Equation 3-3:

$$\text{Fuel}_{\text{Road Category}} = (\text{Vehicle population}) \cdot (\text{Average distance travelled/year}) \cdot (\text{Fuel Consumption Ratio})$$

These parameters are different for each vehicle type; therefore, MGEM 05 calculates fuel use by division into relevant types. On-road vehicles are separated into seven major types, identical to those used by the U.S. EPA in its *MOBILE* Emissions Factor Model.

▪ Vehicle Populations

Two separate vehicle in operation (VIO) databases are used to develop the complete vehicle population profile. Light-duty VIO data sets for 1989–2003 (DesRosiers) have been combined with commercial VIO data sets for 1994–2001 (Polk). Commercial vehicle estimates for 1989 (Environment Canada, 1996) provide an anchor point for the interpolation of the intervening years 1990–1993. Motorcycle data were obtained from Statistics Canada (#53-219) up to and including 1998. Motorcycle data for subsequent years are currently extrapolated. Because the territories are not covered by the commercial databases, Statistics Canada's publication #53-219 provided population data for all vehicles in the Canadian territories from 1990 to 1998, while subsequent years use the Canadian Vehicle Survey (CVS; Statistics Canada, #53F0004).

▪ Technology Penetration

While a simple division of fuel consumption by vehicle type enables the allocation of emissions of carbon to different vehicle categories, it does not take into account the effect that different pollution control devices have on emission rates. To account for the effects that these technologies have on emissions of CH_4 and N_2O, estimates of the number and types of vehicles equipped with catalytic converters and other controls were developed. LDGVs and LDGTs were both further subdivided. Five types of pollution control technology were defined:

- Tier 1 three-way catalyst;
- Tier 0 three-way catalyst (new);
- Tier 0 three-way catalyst (aged);
- oxidation catalyst; and
- non-catalyst.

Vehicles without emission controls were the norm in Canada in the 1960s. Non-catalyst-controlled vehicles were brought to market in the late 1960s. Emission control technology on these included modifications to ignition timing and air-fuel ratios, exhaust gas recirculation, and air injection into the exhaust manifold.[32] Oxidation (two-way) catalytic converters were first used on Canadian vehicles introduced in 1975, and their use continued on production vehicles until the 1987 model year. These so-called two-way converters oxidized hydrocarbons. The three-way (oxidation–reduction) catalytic emission control technology was introduced in Canada in 1980 (Philpott, 1993). Typical ancillary equipment included carburetors with simple electronic ignition. Later, for the 1984 model year, a portion of the fleet was equipped with electronic computer-controlled fuel injection, which became an integral part of the emission control system. By 1990, such computer systems were standard equipment on all gasoline vehicles. The broad category of control technologies produced from the time three-way catalytic converters were introduced up until 1993 has become known in North America as Tier 0 emission control. Tier 0 catalytic converter technology is further subdivided into "new" and "aged" types — the "new" subcategory representing units less than one year old. Tier 1, a more advanced emission control technology, was introduced to North American LDGVs in 1994. It consists of an improved three-way catalytic converter under more sophisticated computer control.

As noted, five technology categories were assigned in the LDGV and LDGT classes, each with a unique emission factor. In these two classes, the categories are based solely on catalytic control technology. All emission factors used are listed in the transport emission factor table (Table A13-5) located within Annex 13.

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[32] Note that no separate category was used for vehicles without emission control, since these have virtually the same GHG emissions as those with non-catalytic control.

Detailed sales information was not available for vehicles other than LDGVs and LDGTs. For other categories, it was necessary to employ an estimated split of significant emission control technologies.

- **Fuel Consumption Ratios**

FCRs, in litres of fuel per hundred kilometres, are also available in more detail for light-duty gasoline transport than for the other vehicle categories. Fleet-average car and light-duty truck FCRs by model year were obtained from Transport Canada (2002) and the U.S. EPA (Heavenrich and Hellman, 1996). FCRs are determined by standard vehicle laboratory tests. However, recent research has shown that real-world fuel use is consistently higher than laboratory-generated data. Based on studies performed in the United States, on-road vehicle fuel consumption figures in the MGEM 05 have been adjusted to 25% above the laboratory FCR ratings (Maples, 1993). Average FCRs for all operating vehicles within each subcategory of LDGVs and LDGTs are calculated by apportioning the model-year consumption data according to the vehicle age and control technology distribution. FCR estimates for classifications other than light-duty cars and trucks have been set to values recommended by the IPCC/OECD/IEA (1997).

- **Vehicle Kilometres Travelled (Vkmt's)**

Estimates for distances travelled by each class of vehicle were from Environment Canada (1996). This information was based upon Statistics Canada data and surveys performed in the late 1980s. However, these surveys included only personal-use vehicles. Since it is likely that Canadian driving habits have changed in the interim, these data are less reliable than most of the other statistics used within MGEM 05.

- **Road-Taxed Fuel**

In an effort to improve accuracy, a balancing algorithm has been incorporated into the model. A comparison of two estimates of off-road fuel consumption is made. As indicated above, using Statistics Canada data, off-road use can be calculated as the difference between total apparent consumption and that used for on-road use. The primary computation of off-road consumption is made on the basis of internally calculated on-road fuel use. The other estimate is obtained using on-road vehicle road-taxed sales data for diesel oil and gasoline (Statistics Canada, CANSIM Table 405-0002). Statistics Canada reports data on the sales of fuel upon which road taxes are paid. The difference between total gasoline or diesel oil used for ground (non-rail) transport and road tax data constitutes a second estimate of off-road use. Sales data from provincial tax records are gathered in a much different manner from the surveys that Statistics Canada uses for most other energy data, as published in the RESD (Statistics Canada, #57-003). Consequently, the two off-road fuel use estimates differ. However, it is assumed that the values agree within a certain window of accuracy. MGEM 05 is currently programmed to accept a ±20% difference between the two estimates. If the value obtained from the internally calculated on-road figure is not within 20% of the sales-derived value, vehicle distance travelled is corrected by the ratio required to bring calculated off-road consumption within the desired range. All diesel and gasoline vehicle subcategories are independently compared and corrected by the model as required. Estimated on-road fuel use and emissions have been calculated on the basis of the corrected vehicle distances travelled.

Railways (CRF Category 1.A.3.c)

In Canada, locomotives are powered primarily by diesel fuel. Emissions associated with steam trains for tourist use are assumed to be negligible, while those associated with the generation of power for grid electrically driven locomotives are accounted for under electricity production.

The methodology is considered to be a modified IPCC Tier 1 (IPCC/OECD/IEA, 1997) methodology. Fuel consumption data from the RESD (Statistics Canada, #57-003), reported as railways, are multiplied by fuel-specific emission factors (see Annex 13).

Navigation (CRF Category 1.A.3.d)

The UNFCCC uses the title navigation for this category, but lists emissions related to international bunkers under marine.

The emission calculations methodology is considered to be modified IPCC Tier 1 (IPCC/OECD/IEA, 1997), and emission estimates are performed within MGEM 05. Fuel consumption data from the RESD (Statistics Canada, #57-003), reported as domestic marine, are multiplied by fuel-specific emission factors (see Annex 13).

Emission calculations are based on estimates of fuel use reported as being sold to Canadian registered vessels. Inadvertently, some international travel may be included in the domestic inventory, since some domestically registered vessels do travel internationally. Data that would allow an accurate disaggregation of shipping activity by shipping route are not currently available, although the marine industry in Canada is currently engaged in talks to help illustrate the appropriate split.

Other: Transport (CRF Category 1.A.3.e)

This subsector comprises vehicles that are not licensed to operate on roads or highways[33] and the emissions from the combustion of fuel used to propel products in long-distance pipelines.

- **Off-Road Transport**[34]

Non-road or off-road transport (ground, non-rail vehicles) includes emissions from both gasoline and diesel fuel combustion. Vehicles in this subsector include farm tractors, logging skidders, tracked construction vehicles, and mobile mining vehicles.

Industry uses a considerable amount of diesel fuel in non-road vehicles. The mining and construction industries both operate significant numbers of heavy non-road vehicles and are the largest diesel oil users in the group.

Off-road vehicles are handled by a simpler IPCC Tier 1 approach. For these, emissions are based on fuel type, fuel emission factors, and total consumption only. Fuel consumption data are generated by MGEM 05 (see Road-Taxed Fuel under Road Transport above), and estimates are generated with country-specific emission factors (see Annex 13). Off-road emission factors are developed by estimating the relative amounts of fuel consumed by specific groups of equipment (agriculture, forestry, industry, household, inland waterways, two-stroke, four-stroke, gas/diesel) and developing a composite emission factor for each fuel type from sector-specific CORINAIR-based emission factors.

- **Pipeline Transport**

Pipelines[35] represent the only non-vehicular transport in this sector. They use fossil-fuelled combustion engines to power motive compressors that propel their contents. The fuel used is primarily natural gas in the case of natural gas pipelines, but some refined petroleum, such as diesel fuel, is also used. Oil pipelines tend to use electric motors to operate pumping equipment.

Combustion-related GHG emissions associated with this equipment are not calculated by MGEM 05. The methodology employed is considered an IPCC Tier 1 sectoral approach. Fuel consumption data from the RESD (Statistics Canada, #57-003), reported as pipelines, are multiplied by fuel-specific emission factors.

3.1.3.3 Uncertainties and Time-Series Consistency

The following individual sector explanations are based on the results reported in *Quantitative Assessment of Uncertainty in Canada's National GHG Inventory Estimates for 2001* (ICF, 2004). Although the study explicitly investigated the 1990–2001 inventory (2003 submission), the relative uncertainty is generally still applicable to subsequent inventory submissions. Within each specific subsector described below, it is indicated if the method evaluated during the study has been modified; only in those cases will the uncertainty not be representative of the current process. For an overarching description of the uncertainty study, please refer to Annex 7 on Uncertainty.

Transport Sector Fossil Fuel Combustion

The Transport sector comprises (i) the mobile sources of transport, including on-road and off-road vehicles, railways, civil aviation, and navigation, and (ii) pipeline transport. The uncertainty in the 2003 inventory year estimates of CO_2 emissions from fossil fuel combustion of mobile sources is estimated at -4% to 0%, indicating that the inventory GHG values are likely overestimates.

Similar to the stationary fuel combustion sources, the uncertainty ranges of approximately a factor of four or more for the 2003 inventory year estimates of the CH_4

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[33] Referred to as non-road or off-road vehicles.

[34] The terms "non-road" and "off-road" are used interchangeably.

[35] Consisting of both oil and gas types.

and the N_2O emissions from Transport sector fossil fuel combustion are attributable to the large uncertainty ranges for several CH_4 and N_2O emission factors.

The uncertainty associated with the total GHG emissions from the mobile source category for 2003 is estimated to be within the range of -3% to 19%, which reflects the predominance of CO_2 in the total GHG emissions from the mobile sources of transport and its relatively low uncertainty estimate.

CO_2 Emissions from Road Transport

The uncertainty associated with CO_2 emissions from on-road vehicles for 2003 is estimated to be within the range of -8% to -3%, relative to the 2003 inventory year estimate for this source category. This implies that the 2003 inventory year estimate for this source category is likely an overestimate. The upward bias in the 2003 inventory year values for this key source category is related to estimated uncertainties for (i) the amount of fuel consumed by the motor gasoline and diesel on-road vehicles and (ii) the CO_2 emission factors for motor gasoline. (The 95% confidence interval uncertainty range for the CO_2 motor gasoline emission factor by McCann [2000] was estimated to be -3% to -1%.)

CO_2 Emissions from Railways

The uncertainty associated with CO_2 emissions from rail transport is estimated to be within the range of -5% to 3%, relative to the 2003 inventory year estimate. In terms of the contribution to the uncertainty in the inventory estimate of this key source category for 2003, it seems that the input variables diesel consumption (with an uncertainty of ±3%) and CO_2 emission factor for diesel (with an uncertainty range of -4% to 2%) were equally responsible. As noted, a sensitivity analysis of this source category, to be conducted subsequently, will facilitate identifying the relative contribution of these two input variables to the uncertainty associated with this category.

CO_2 Emissions from Civil Aviation

The uncertainty associated with the CO_2 emission estimates from civil aviation reported in ICF (2004) is no longer applicable. Since the study was completed, a new method to enhance resolution on the use of fuel purchased in Canada by Canadian airlines has been employed. This has affected the previous historic emissions reported as domestic and reduced them between 40% and 55% annually. The study's reported uncertainty reflects the low uncertainty range associated with the CO_2 emission factor for, and the fuel consumption estimate of, the aviation turbo fuel, which accounted for nearly 97% of the total CO_2 emissions from civil aviation in 2003. There is a rationale to suggest that the expert polled for his opinion on the uncertainty of the activity data (Apparent Consumption of Aviation Fuels) was misled by the configuration of the questions asked. This would have resulted in a lower-than-actual uncertainty estimate.

CO_2 Emissions from Other (or Off-Road) Transport

The off-road transport subsector includes both off-road gasoline and off-road diesel consumption. The uncertainty associated with the off-road mobile transport sources was estimated to be within the range of +4% to +45%, indicating that the 2003 inventory year estimates likely underestimated the CO_2 emissions from this source category. The CO_2 emissions from off-road diesel vehicles accounted for nearly 70% of the total CO_2 emissions from the off-road category in 2003. The main sources of uncertainty for this source category are the uncertainty associated with the 2003 inventory year values of the fuel consumption estimates for off-road gasoline and off-road diesel. Consistent with the inventory estimation methodology for this source category, the off-road diesel fuel consumption is calculated from the on-road diesel fuel consumption residual and the off-road gasoline consumption is calculated from the on-road gasoline consumption residual, both of which are dependent upon dated estimates of vehicle kilometres travelled.

Summary

Generally, for Transport subsectors, the ICF (2004) study merely incorporated previous studies' reported values for the estimated uncertainty surrounding the CO_2, CH_4, and N_2O emission factors (McCann, 2000; SGA, 2000). ICF (2004) included these reports' values along with a limited expert elicitation addressing the uncertainty of the activity data contributing to the Transport subsector estimates within its Monte Carlo analysis.

Additionally, it should be noted that the overestimate of the on-road emissions (-8% to -3%) offsets the underestimate of off-road emissions (4% to 45%) to achieve a composite uncertainty (-4% to 0%) better than either of the individual components.

Some of the weaker portions of the uncertainty surround the acquisition of expert opinions on non-fuel quantity type activity estimates (e.g., vehicle populations, kilometres travelled, motorcycle numbers). Although it was suggested that the vehicle population data supplied by an outside consultant to Environment Canada are 100% accurate, there are indications that the underlying data may be compiled incorrectly. This will only introduce marginal errors in a fuel-constrained model, but it has considerable impact on the attribution of that fuel to specific vehicle types.

3.1.3.4 QA/QC and Verification

Tier 1 QC checks as elaborated in the framework for the QA/QC plan (see Annex 6) were performed on the following six key categories for CO_2 from transport: Civil Aviation, Road Transport, Railways, Navigation, Pipelines, and Other Transport. No significant anomalies were detected. In addition, certain verification steps were performed during the model preparation stage.

Since MGEM 05 uses national fuel data defined by type and region combined with country-specific emission factors, primary scrutiny is applied to the vehicle population profile, as this dictates the fuel demand per vehicle category and, hence, emission rates and quantities. Recently, interdepartmental partnerships have been developed among Environment Canada, Transport Canada, and NRCan to facilitate the sharing of not only data but also knowledge and history of vehicle population data. This increased perspective fosters a better understanding of actual vehicle use and subsequently should promote better modelling and emissions estimating. With support from Transport Canada, Statistics Canada publishes the CVS, a quarterly report that provides both vehicle population and kilometrage in aggregated regional classes. It provides alternative interpretation of provincial registration files and can therefore corroborate the commercially available data sets mentioned above. Unfortunately, the resolution necessary for emissions modelling is unavailable from the CVS, and therefore it cannot replace the annually purchased data sets.

3.1.3.5 Recalculations

The underlying fuel-use data were revised for 2002, as was the vehicle population profile, following the acquisition of additional data sets (light-duty VIO — 2003 [Polk]). Transport estimates were recalculated accordingly. Also, by virtue of employing MGEM 05 for transportation estimates and its inherent ability to carry full-resolution values (no rounding of intermediate calculations), some final results have changed marginally.

Major recalculations are also present in the estimates of domestic aviation due to the incorporation of flight activity data (t-km and passenger movements) within the fuel allocation methodology.

3.1.3.6 Planned Improvements

The method currently used to evaluate emissions associated with the Transport sector provides for a fuel-constrained estimate and thus contributes the least uncertainty to the process. However, the previous (spreadsheet) model was limited in its ability to accommodate the volume of high-resolution data recently made available through increased data-sharing partnerships and reporting. It is expected that MGEM 05 will continuously evolve to exploit the power of the database model that will directly appropriate data from these new sources.

In general, future improvements will concentrate on revealing more details with respect to activity data.[36] These will include:

- higher-resolution vehicle population profiles, allowing for annual age distribution of technology penetration (currently static) and greater vehicle subcategory disaggregation;
- improved Vkmt estimates, to better allocate fuel consumption regionally; and
- industry cooperation with respect to obtaining marine (waterborne navigation) activity data, allowing more accurate disaggregation into domestic and international.

With respect to vehicle populations, the current data sets contributing to the Canadian vehicle population profile have been prepared by one of two North American firms that use similar methods to identify specific model year counts from provincial vehicle registries. Each firm provides a unique data set; when combined, the data sets define the entire Canadian fleet, except for the Canadian territories, whose vehicle populations are estimated using the CVS.

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[36] Ultimately fuel consumption.

These data sets are primarily prepared as a market analysis tool for industries associated with the North American automobile industry. They are used to regionally define vehicle population profiles and have become a standard source of information for new business establishments such as auto parts suppliers. Because of the continental acceptance as the industry-leading data sources, they are deemed the best available.

New estimating tools are becoming available, which can accommodate enhanced vehicle class definitions, fuel types, and regions. As a result, the older market analysis data sets are undergoing scrutiny in an attempt to understand data anomalies. These include, specifically, increases observed in model years that have not been available for high-volume sale for 15–20 years. It is planned, therefore, to incorporate the results of some of these new tools in the future.

3.1.4 OTHER SECTORS (CRF CATEGORY 1.A.4)

3.1.4.1 Source Category Description

This category consists of three subsectors: commercial/institutional, residential, and agriculture/forestry/fishing. Emissions consist primarily of fuel combustion related to space and water heating. Emissions from the use of transportation fuels in these subsectors are allocated to the Transport sector (Section 3.1.3). Biomass[37] combustion is a significant source of emissions in the residential sector. The CO_2 emissions from biomass are reported separately in the CRF tables as memo items and are not included in Energy Sector totals.

In 2003, the Other Sectors category contributed about 87 Mt (or 12%) of Canada's total GHG emissions, with an overall growth of about 20% since 1990. Within the Other Sectors category, the residential sector contributed about 45 Mt (or 52%) of the emissions, followed by a 39 Mt (or 45%) contribution from the commercial and institutional category, which also includes emissions from public administration (which is made up of federal, provincial, and municipal establishments). GHG emissions grew by 51% for the commercial/institutional sector since 1990. Refer to Table 3-5 for additional details.

TABLE 3-5: **Other Sectors GHG Contribution**

GHG Source Category	1990	2002	2003
		kt CO_2 eq	
Other Sectors TOTAL	**72 000**	**81 000**	**87 000**
Commercial/Institutional	25 800	35 400	39 000
Residential	44 000	44 000	45 000
Agriculture/Forestry	2 420	2 110	2 210

3.1.4.2 Methodological Issues

Emissions from this sector are calculated according to the methodology described in Annex 2. Methodological issues specific to subsectors are described below. Emissions from the combustion of transportation fuels are allocated to the Transport category.

Commercial/Institutional (CRF Category 1.A.4.a)

Emissions are based on fuel-use data reported as commercial and public administration in the RESD (Statistics Canada, #57-003).

Residential (CRF Category 1.A.4.b)

Emissions are based on fuel-use data reported as residential in the RESD (Statistics Canada, #57-003).

The methodology for biomass combustion from residential firewood is detailed in the CO_2 Emissions from Biomass section (Section 3.3.2); although CO_2 emissions are not accounted for in the national residential GHG total, the CH_4 and N_2O emissions are reported here.

Agriculture/Forestry/Fishing (CRF Category 1.A.4.c)

This category includes emissions from stationary fuel combustion in the agricultural, forestry, and fisheries industries. However, emission estimates are included for the agriculture and forestry portion of the subsector only. Fishery emissions are reported typically under either transportation or other manufacturing (i.e., food processing) categories. Mobile emissions associated with this subsector were not disaggregated and are included as off-road or marine emissions reported under Transport (Section 3.1.3). Emissions are based on fuel-use data reported as agriculture and forestry in the RESD (Statistics Canada, #57-003).

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[37] Typically firewood.

3.1.4.3 Uncertainties and Time-Series Consistency

The estimated uncertainty for the Other Sectors category ranges from -4% to 41% for all gases and from -3% to 2% for CO_2. Refer to the Uncertainty annex (Annex 7) for a detailed discussion on the ICF (2004) uncertainty study and additional uncertainty values for the Other Sectors category.

The underlying fuel quantities and CO_2 emission factors have low uncertainties, because they are predominantly commercial fuels, which have consistent properties and accurate tracking. Although the non-CO_2 emissions from biomass combustion contributed only 5% to the total Residential subcategory, its CH_4 (-90% to 1500%) and N_2O (-65% to 1000%) uncertainties are high due to the uncertainty associated with their emission factors. As stated in the Energy Industries category, additional expert elicitation is required to improve the CH_4 and N_2O uncertainty estimates for some of the emission factor uncertainty ranges and probability density functions developed by the ICF (2004) study, since insufficient time was available to have these assumptions reviewed by industry experts.

These estimates are consistent over the time series.

3.1.4.4 QA/QC and Verification

Other Sectors, identified as a key category, underwent Tier 1-level QC checks as set out in the framework for the QA/QC plan (see details and references in Annex 6) and in a manner consistent with Good Practice Guidance. No mathematical errors were found during the QC checks, although a number of labelling and referencing problems were identified. Corrections to the spreadsheets and model, to fix these issues, will assist in producing accurate and error-free future inventories. The data, methodologies, and changes related to the QC activities are documented and archived in both paper and electronic form.

3.1.4.5 Recalculations

The underlying fuel-use data were revised for 2002, and the estimates were recalculated accordingly.

CH_4 and N_2O emissions from the use of spent pulping liquor were incorrectly reported in the Residential subcategory. Emissions from the use of spent pulping liquor have been reallocated to the Pulp, Paper and Print subcategory, resulting in a revised estimate for the Residential subcategory.

3.1.4.6 Planned Improvements

Future improvement plans for the Other Sectors category will include a review of the residential biomass model.

3.1.5 OTHER: ENERGY — FUEL COMBUSTION ACTIVITIES (CRF CATEGORY 1.A.5)

The UNFCCC Reporting Guidelines assign military fuel combustion to this subsector. However, emissions related to military vehicles have been included in the Transport category, while stationary military fuel use has been included under the Commercial/Institutional category (Section 3.1.4) due to fuel data allocation in the RESD (Statistics Canada, #57-003). This is a small source of emissions.

3.2 FUGITIVE EMISSIONS (CRF CATEGORY 1.B)

Fugitive emissions from fossil fuels are intentional or unintentional releases of GHGs from the production, processing, transmission, storage, and delivery of fossil fuels.

Released gas that is combusted before disposal (e.g., flaring of natural gases at oil and gas production facilities) is considered a fugitive emission. However, if the heat generated during combustion is captured for use (e.g., heating) or sale, then the related emissions are considered fuel combustion emissions.

The two categories considered in the inventory are fugitive releases associated with solid fuels (coal mining and handling) and releases from activities related to the oil and natural gas industry.

In 2003, the Fugitives category accounted for about 54 Mt (or 7.3%) of Canada's total GHG emissions, with a 42% growth in emissions since 1990. Over 98% of the growth in the Fugitives category is from oil and gas production, processing, transmission, and distribution activities, with the remaining 2% originating from coal mining. Refer to Table 3-6 for more detail.

TABLE 3-6: Fugitive GHG Contribution

		kt CO_2 eq	
GHG Source Category	**1990**	**2002**	**2003**
Fugitive Sources TOTAL	**37 900**	**54 500**	**54 000**
Solid Fuels — Coal Mining	2 000	1 000	1 000
Oil and Natural Gas	36 000	53 500	53 000
Oil[1]	8 600	13 000	13 000
Natural Gas[1]	17 000	24 000	24 000
Venting[2]	4 500	8 100	7 800
Flaring[2]	5 800	8 000	8 000

Notes:

1 All fugitive sources except venting and flaring.

2 Both oil and gas activities.

3.2.1 SOLID FUELS (CRF CATEGORY 1.B.1)

3.2.1.1 Source Category Description

Coal in its natural state contains varying amounts of CH_4. In coal deposits, CH_4 is either trapped under pressure in porous void spaces within the coal formation or adsorbed to the coal. The pressure and amount of CH_4 in the deposit vary depending on the grade, the depth, and the surrounding geology of the coal seam. During coal mining, post-mining activities, and coal-handling activities, the natural geologic formations are disturbed, and pathways are created that release the pressurized CH_4 to the atmosphere. As the pressure on the coal is lowered, the adsorbed CH_4 is released until the CH_4 in the coal has reached equilibrium with the surrounding atmospheric conditions.

Mining activity emission sources are from the exposed coal surfaces, coal rubble, and the venting of CH_4 from within the deposit. Post-mining activities such as preparation, transportation, storage, or final processing prior to combustion also release CH_4.

Fugitive emissions from solid fuel transformation (such as fugitive losses from the opening of metallurgical coking oven doors) are not estimated due to lack of data. Other sources of solid fuel transformation emissions are not known. These sources are thought to be insignificant.

3.2.1.2 Methodological Issues

An inventory of fugitive emissions from Canadian coal mining operations was developed in the early 1990s and used as the basis for the estimates presented here. The estimates from the inventory (King, 1994) were divided by appropriate coal production data to arrive at emission factors for subsequent years. A summary of the methodology used in the original study is provided here.

The method used by King (1994) to estimate emission rates from coal mining (emission factors in Annex 13) was based on a modified procedure from the Coal Industry Advisory Board. It consists of a hybrid of IPCC Tier 3- and IPCC Tier 2-type methodologies, depending on availability of mine-specific data. It separates underground mining emissions from surface mining emissions and includes post-mining activity emissions within each of those activities.

Underground Mines

King (1994) estimated emissions for underground mines on a mine-specific basis by summing emissions from the ventilation system, degasification systems, and post-mining activities.

Emissions from the mine shaft ventilation system were estimated (if measured data were not available) using Equation 3-4:

Equation 3-4:

$$Y = 4.1 + (0.023 * X)$$

where:

Y = cubic metres (m^3) of CH_4 per tonne (t) of coal mined

X = depth of mine in metres (m)

Emissions from post-mining activities were estimated by assuming that 60% of the remaining coal CH_4 (after removal from the mine) is emitted to the atmosphere before combustion. If the gas content of the mined coal was not known, then it was assumed that the CH_4 content was 1.5 m^3/t (the world average CH_4 content of coals). Emissions from post-mining activities are included in the coal production emission factors.

Emissions in the national inventory were estimated by multiplying coal production data (from Statistics Canada, #45-002) by the emission factors in Annex 13.

Surface Mines

For surface mines, it was assumed that the average CH_4 content of surface-mined bituminous or sub-bituminous coals was 0.4 m^3/t (based on U.S. measured data). Of this, it was assumed that 60% is released to the atmosphere before combustion (King, 1994). For lignite, gas content values determined previously for Canada were used (Hollingshead, 1990).

A significant source of emissions from surface mines is the surrounding unmined strata. An attempt was made to account for this by applying a high-wall adjustment to account for the outgassing of the surrounding unmined strata to a depth of 50 m below the mining surface. It was estimated that base emission factors for surface mining should be increased 50% (King, 1994) to account for this. The emission factors shown in Annex 13 have been adjusted accordingly.

Emissions in the national inventory were estimated by multiplying coal production data (from Statistics Canada, #45-002) by the emission factors in Annex 13.

3.2.1.3 Uncertainties and Time-Series Consistency

The CH_4 uncertainty estimate for fugitive emissions from coal mining is estimated to be in the range of -30% to 130% (ICF, 2004). The production data are known to a high degree of certainty (±2%). On the other hand, a very significant uncertainty (-50% to 200%) was estimated for the emission factors. It is our view that further expert elicitation is required to validate assumptions made by the study in the development of the probability density functions and uncertainty ranges of emission factors and activity data from surface and underground mining activities. IPCC default uncertainty values were assumed for Canada's country-specific emission factors, and these will need to be reviewed. The use of IPCC default values will not result in a representative uncertainty estimate when country-specific information is used. Refer to the Uncertainty annex (Annex 7) for more details on the study.

3.2.1.4 QA/QC and Verification

Coal mining (CH_4 emissions) was identified as a key source category and underwent Tier 1 QC checks as set out in the framework for the QA/QC plan (see details and references in Annex 6) and in a manner consistent with Good Practice Guidance. Checks included a review of the estimation model, activity data, emission factors, time-series consistency, transcription errors, reference material, conversion factors, and units labelling, as well as sample emission calculations.

While no mathematical errors were found during the QC checks, some labelling and referencing problems were revealed. Updates to the spreadsheets, to correct these issues, will help to produce accurate and error-free future inventories. The data, methodologies, and changes related to the QC activities are documented and archived in both paper and electronic form.

3.2.1.5 Recalculations

No recalculations were made to this sector.

3.2.1.6 Planned Improvements

No improvements are planned for this category.

3.2.2 OIL AND NATURAL GAS (CRF CATEGORY 1.B.2)

3.2.2.1 Source Category Description

The Oil and Natural Gas sector includes fugitive emissions from conventional upstream oil and gas production, unconventional oil production, and natural gas distribution. Fuel combustion emissions from facilities in the oil and gas category (when used for energy) are included under the Manufacture of Solid Fuels and Other Energy Industries sector (Section 3.1.1).

This category has three main subcategories: Conventional Upstream Oil and Gas Production, Unconventional Crude Oil Production, and Natural Gas Distribution.

Conventional Upstream Oil and Gas Production

This subsector includes all fugitive emissions from exploration, production, processing, and transmission of oil and natural gas. Emissions may be the result of designed equipment leakage (bleed valves, fuel gas-operated pneumatic equipment), imperfect seals on equipment (flanges and valves), accidents, spills, and deliberate vents.

The Conventional Upstream Oil and Gas subsector is vast and complex. The sources have been divided into major categories:

- *Oil and Gas Well Drilling*: Oil and gas well drilling is a minor emission source. The emissions are from drill stem tests, release of entrained gas in drilling fluids, and volatilization of invert drilling fluids.
- *Oil and Gas Well Servicing*: Well servicing is also a minor emission source. The emissions are mainly from blow-down treatments for shallow gas wells. Emissions from venting of mud tanks and depressurization of piping, wells, and vessels could also be a potential source; however, there are limited data available, and the source is considered negligible.
- *Natural Gas Production*: Natural gas is produced exclusively at gas wells or in combination with conventional oil, heavy oil, and crude bitumen production wells with gas conservation schemes. The emission sources associated with natural gas production are wells, gathering systems, field facilities, and gas batteries. The majority of emissions result from equipment leaks, such as leaks from seals; however, venting from the use of fuel gas to operate pneumatic equipment and line-cleaning operations are also significant sources.
- *Light/Medium Oil Production*: This type of production is defined by wells producing light- or medium-density crude oils (i.e., density <900 kg/m^3). The emissions are from the wells, flow lines, and batteries (single, satellite, and central). The largest sources of emissions are the venting of solution gas and evaporative losses from storage facilities.
- *Heavy Oil Production*: Heavy oil is defined as having a density above 900 kg/m^3. This viscous liquid requires a special infrastructure to produce. There are generally two types of heavy oil production systems: primary and thermal. The emission sources from both types are wells, flow lines, batteries (single and satellite), and cleaning plants. The largest source is venting of casing and solution gas.
- *Crude Bitumen Production*: Crude bitumen is a highly viscous, dense liquid that cannot be removed from a well using primary production means. Enhanced *in situ* recovery is required to recover the hydrocarbons from the formation. The sources of emissions are wells, flow lines, satellite batteries, and cleaning plants. The main source of emissions is the venting of casing gas.
- *Gas Processing*: Natural gas is processed before entering transmission pipelines to remove contaminants and condensable hydrocarbons. There are four different types of plants: sweet plants, sour plants that flare waste gas, sour plants that extract elemental sulphur, and straddle plants. Straddle plants are located on transmission lines and recover residual hydrocarbons. They have a similar structure and function and so are considered in conjunction with gas processing. The largest source of emissions is from equipment leaks.
- *Natural Gas Transmission*: Virtually all of the natural gas produced in Canada is transported from the processing plants to the gate of the local distribution systems by pipelines. The volumes transported by truck are insignificant and assumed negligible. The gas transmission system emission sources are from equipment leaks and process vents. Process vents include activities such as compressor start-up and purging of lines during maintenance. The largest source of emissions is equipment leaks.
- *Liquid Product Transfer*: The transport of liquid products from field processing facilities to refineries or distributors produces emissions due to loading and unloading of tankers, storage losses, equipment leaks, and process vents. The transport systems included are liquefied petroleum gas (LPG) (by both surface transport and high-vapour-pressure pipeline systems), pentane-plus systems (by both surface transport and low-vapour-pressure pipeline systems), and crude oil pipeline systems.
- *Accidents and Equipment Failures*: Fugitive emissions can result from human error or extraordinary equipment failures in all segments of the conventional upstream oil and gas industry. The major sources are emissions from pipeline ruptures, well blowouts, and spills. Emissions from the disposal and land treatment of spills are not included due to insufficient data.

- *Surface Casing Vent Blows and Gas Migration*: At some wells, fluids will flow into the surface casing from the surrounding formation. Depending on the well, the fluids will be collected, sealed in the casing, flared, or vented. The vented emissions are estimated in this section. At some wells, particularly in the Lloydminster (Alberta) region, gas may migrate outside of the well, either from a leak in the production string or from a gas-bearing zone that was penetrated but not produced. The emissions from the gas flowing to the surface through the surrounding strata have been estimated.

Unconventional Crude Oil Production

This subsector includes emissions from oil sand open pit mining operations and heavy/bitumen oil upgrading facilities in Canada. The fugitive emissions are primarily CH_4 from the open mine face and from methanogenic bacteria in the mine tailings settling ponds.

Emissions related to methanogenic bacteria in the tailings ponds continue to be studied by the operators. It is believed that with the planned implementation of new bitumen recovery techniques, the lighter hydrocarbons in the waste streams of the current processes will be reduced, and the emissions will be correspondingly lowered.

Natural Gas Distribution

The natural gas distribution system receives high-pressure gas from the gate of the transmission system and distributes this through local pipelines to the end user. The major emission sources are station vents during maintenance, which account for about half the emissions.

3.2.2.2 Methodological Issues

Conventional Upstream Oil and Gas Production

Fugitive emission estimates from the conventional upstream oil and gas industry for 1990–1996 are based on a study by Clearstone Engineering (CAPP, 1999). A summary of the method is provided here; details are available in the report. The emission estimates result from a rigorous engineering study based on the various products, processes, and infrastructure used in the Canadian conventional upstream oil and gas industry.

Emission factors in the study were obtained from published sources (Radian International, 1997) or estimated based on industry-specific information, such as the average size of a mud pit, storage tank, etc.

The activity data used in the study were for typical processing plant equipment schedules, production rates, gas–oil ratios, etc., collected from various sources, such as the Alberta Energy and Utilities Board, NRCan, and provincial energy ministries.

The method used in the original study (CAPP, 1999) is considered a rigorous IPCC Tier 3-type method.

After 1996, the estimates for fugitive emissions from the conventional upstream oil and gas industry were made in a manner that was different from that utilized for the 1990–1996 period (estimates for which are based directly on the CAPP [1999] study). Emission data for 1996 were extrapolated by the changes in relevant production data for the following years. This method was used on an interim basis and will continue to be used until new data become available from a further study. The data used for the extrapolations are shown in Table 3-7.

TABLE 3-7: Oil and Gas Activities and Extrapolation Data

Activity	Extrapolation Data
Flaring	Gross New Production of Natural Gas (Statistics Canada, #26-006)
Raw CO_2	Net Withdrawals of Natural Gas (Statistics Canada, #26-006)
Oil and Gas Well Drilling	Constant at 1996 levels
Oil and Gas Well Servicing	Constant at 1996 levels
Natural Gas Production	Gross New Production of Natural Gas (Statistics Canada, #26-006)
Light/Medium Oil Production	Total Production of Light & Medium Crude Oil (Statistics Canada, #26-006)
Heavy Oil Production	Total Production of Heavy Oil (Statistics Canada, #26-006)
Crude Bitumen Production	Total Production of Crude Bitumen (Statistics Canada, #26-006)
Natural Gas Processing	Net Withdrawals of Natural Gas (Statistics Canada, #26-006)
Natural Gas Transmissions	Natural Gas Transmission Pipeline Length (Statistics Canada, #57-205)
Liquid Product Transport	Constant at 1996 levels
Accidents & Equipment Failures	Constant at 1995 levels (1996 was an anomalous year)
Surface Casing, Vent Blows, and Gas Migration	Constant at 1996 levels

Sources:

Statistics Canada, *Supply and Disposition of Crude Oil and Natural Gas*, 1990–1998, Catalogue No. 26-006.

Statistics Canada, *Natural Gas Transportation and Distribution*, 1990–1998, Catalogue No. 57-205.

Unconventional Crude Oil Production

The emission data reported are based on estimates made by the operators of the unconventional crude oil production facilities. These data were compiled in a study for CAPP (1999). Descriptions of the methods are available in the full report. Due to lack of new data, emissions have been assumed constant since 1996.

Natural Gas Distribution

The emission estimates were derived from a study for the Canadian Gas Association (Radian International, 1997). The study estimated the emissions from the Canadian gas pipeline industry for the years 1990 and 1995.

Emissions in the study were calculated based upon emission factors from the U.S. EPA, other published sources, and engineering estimates.

The activity data in the study were obtained from published sources and from specialized surveys of gas distribution system companies. The surveys obtained information on schedules of equipment, operation parameters of equipment, pipeline lengths used in the Canadian distribution system, etc.

General emission factors were developed for the distribution system based on the study data (Radian International, 1997) and gas distribution pipeline distances published by Statistics Canada (#57-205).

The original study method is a rigorous IPCC Tier 3 approach.

3.2.2.3 Uncertainties and Time-Series Consistency

The emission data used in the inventory from 1990 to 1996 are directly from the CAPP (1999) study; the data from 1997 to the present are based on an extrapolation of the emission rates determined from that study. The uncertainty of the more recent inventory years is greater due to the extrapolation.

The overall uncertainty for fugitive emissions from the oil and gas industry is estimated to be in the range of -10% to 9%. CH_4 emissions, contributing about 71% (39 000 kt) of the 53 000 kt GHG emissions from fugitive oil and gas, have an estimated uncertainty range of -7% to 15%.

The uncertainty estimate associated with venting and flaring ranges from -38% to 16% for all gases, while the uncertainty estimate associated with natural gas systems is 1% to 28% and with oil system is -29% to 13%. Emissions from natural gas and oil systems are attributed to leaks from production, transportation, processing, storage, transmission, and distribution activities (ICF, 2004). Refer to the Uncertainty annex (Annex 7) for a detailed discussion of the ICF (2004) uncertainty study and its applicability to the 2003 inventory estimates.

To improve the accuracy of the GHG emission estimates for the conventional upstream oil and gas systems, Environment Canada has commissioned new work to update the CAPP (1999) study. As stated in the improvement plan, results from the study will be reviewed and (where appropriate) used to update and improve the quality of the national inventory's emission estimation model.

3.2.2.4 QA/QC and Verification

Tier 1 QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) were performed on the CO_2 estimates for the following key source subcategories:

- Oil and Natural Gas Industries, CH_4; and
- Oil and Natural Gas Venting and Flaring, CO_2.

No significant mathematical errors were found during the QC checks; however, some labelling and referencing problems were identified. Changes to the spreadsheet model, to correct these issues, will help to produce accurate and error-free future inventories. The data, methodologies, and changes related to the QC activities are documented and archived in both paper and electronic form.

3.2.2.5 Recalculations

Recalculation activities were performed for the 2000–2002 time series on the fugitive estimate for light and medium oil production. The activity data in the estimation model were linked to the "Net Withdrawals of Natural Gas" instead of the "Total Production of Light and Medium Crude Oil."

3.2.2.6 Planned Improvements

Environment Canada is currently conducting another detailed study of the fugitive emissions from the upstream oil and gas industry. Results will be incorporated in future methodological improvement of the estimation model for the fugitive oil and gas category. Refer to the discussion in Section 3.1.1.6 for more details.

3.3 MEMO ITEMS (CRF CATEGORY 1.C)

3.3.1 INTERNATIONAL BUNKER FUELS (CRF CATEGORY 1.C.1)

According to the IPCC guidelines (IPCC/OECD/IEA, 1997), emissions resulting from fuels sold for international marine and air transportation should not be included in national inventory totals, but should be reported separately as emissions from "bunkers" or "international bunkers." Historically, in the Canadian inventory, any fuel reported by Statistics Canada as having been sold to foreign-registered marine or aviation carriers was excluded from national inventory emission totals.

However, it has not been clear whether all of the fuel sold to foreign-registered carriers in Canada is used for international transport. More importantly, it has become apparent that not all of the fuels sold to domestically registered carriers are consumed within the country. The UNFCCC and the IPCC are currently developing clearer guidelines for bunkers, and modified statistical procedures may be required to track bunker fuels more accurately.

3.3.1.1 Aviation (CRF Category 1.C.1.A)

Emissions have been calculated using the same methods listed in the section Civil Aviation (see Section 3.1.3.2). Fuel-use data are reported as foreign airlines in the RESD (Statistics Canada, #57-003). This year, however, as mentioned previously, a method developed to estimate the portion of fuel sold to domestic airlines and used for international flights was adopted to allow a further disaggregation of the fuel sold to domestic carriers. This additional quantity augments that sold directly to foreign airlines, and the sum represents the total fuel allocated to international aviation. The associated emissions are reported separately in the CRF under Bunker Fuels, Aviation.

This adopted method uses data that report total tonne-kilometres flown by all Canadian airlines globally and stratifies this as either international or domestic. This was chosen as a proxy of fuel consumption due to its acceptable correlation (high R^2 coefficient: 93.5%) when both the fuel consumption and t-km are known. An assumption that 69% of the international t-km are flown using domestically purchased fuel achieves maximum corroboration with both SAGE and AERO2K, flight path models operated by the United States and the United Kingdom, respectively.

3.3.1.2 Marine (CRF Category 1.C.1.B)

Emissions have been calculated using the same methods listed in the section Navigation (see Section 3.1.3.2). Fuel-use data are reported as foreign marine in the RESD (Statistics Canada, #57-003).

3.3.2 CO_2 EMISSIONS FROM BIOMASS

As per the UNFCCC Reporting Guidelines, CO_2 emissions from the combustion of biomass used to produce energy are not included in the Energy Sector totals but are reported separately as memo items. They are accounted for in the LULUCF Sector and are recorded as a loss of biomass (forest) stocks. CH_4 and N_2O emissions from the combustion of biomass fuels for energy are reported in the fuel combustion section in the appropriate categories.

Biomass emissions have been grouped into two main sources: residential firewood and industrial wood wastes.

3.3.2.1 Residential Firewood

Firewood is used as a primary or supplementary heating source for many Canadian homes. Combustion of firewood results in CO_2, CH_4, and N_2O emissions.

The calculation of GHG emissions from the combustion of residential firewood is based on estimated fuel use and technology-specific emission factors. Fuel-use data are based on the CAC Inventory (Environment Canada, 1999). Statistics Canada and NRCan residential fuel-use data were not used, since they appear to greatly underestimate firewood consumption (as a significant portion of firewood consumed in Canada is not from commercial sources).

Firewood consumption data were collected through a survey of residential wood use for the year 1995 (Canadian Facts, 1997). These data were collected by province and grouped into five major appliance-type categories:

1) Conventional stoves
    - non-airtight
    - airtight, non-advanced technology
    - masonry heaters
2) Stove/fireplace inserts with advanced technology or catalyst control
    - advanced-technology fireplaces
    - advanced-technology stoves
    - catalytic fireplaces
    - catalytic stoves
3) Conventional fireplaces
    - without glass doors
    - with non-airtight glass doors
    - with airtight glass doors
4) Furnaces
    - wood-burning fireplaces
5) Other equipment
    - other wood-burning equipment

The firewood consumption data for the other years were extrapolated based on the number of houses in each province using wood as a principal or supplementary heat source (from Statistics Canada, 1995) in relation to 1995.

The N_2O and CH_4 emission factors for different wood-burning appliances are from the U.S. EPA's AP-42, supplement B (EPA, 1996). These emissions are included in the fuel combustion sector of the inventory.

The emission factors for CO_2 are from an Environment Canada study (ORTECH Corporation, 1994).

GHG emissions were calculated by multiplying the amount of wood burned in each appliance by the emission factors.

3.3.2.2 Industrial Wood Wastes

A limited number of data for industrial firewood and spent pulping liquor are available in the RESD (Statistics Canada, #57-003). The Statistics Canada data for 1990 and 1991 were combined for the Atlantic provinces, as were the data for the Prairie provinces. Individual provincial data were delineated by employing a data comparison with the 1992 RESD data. For 1992, the data for Newfoundland and Labrador and Nova Scotia were also combined, and there were no comparable data to allow separation of these provinces. Emissions are listed under Nova Scotia.

Industrial firewood CO_2 and CH_4 emission factors are those assigned by the U.S. EPA to wood fuel/wood waste (EPA, 1996). For CH_4, emission factors were given for three different types of boilers; the emission factor used in the Canadian inventory is an average of the three.

Industrial firewood N_2O emission factors are those assigned to wood fuel/wood waste (Rosland and Steen, 1990; Radke et al., 1991) (see Annex 13).

The emission factor for CO_2 from spent pulping liquor combustion was developed based on two assumptions:

1) The carbon content of spent pulping liquor is 41% by weight.
2) There is a 95% conversion of the carbon to CO_2.

The emission factor (EF) is therefore calculated as follows (Jaques, 1992):

$$\begin{aligned} EF\ CO_2 &= 0.41 * 0.95 * (44\text{ g/mol} / 12\text{ g/mol}) \\ &= 1.428\ CO_2\text{/spent pulping liquor} \end{aligned}$$

(Note: This emission factor has been rounded to 1500 g/kg, as illustrated in Annex 13.)

Emissions are calculated by applying emission factors to the quantities of biomass combusted. The CH_4 and N_2O emissions are included in the manufacturing sector of the inventory.

3.4 OTHER ISSUES

3.4.1 COMPARISON OF SECTORAL AND REFERENCE APPROACHES

The reference approach was compared with the sectoral approach as a check of combustion-related emissions. The check was performed for all years from 1990 to 2003 and is an integral part of the CRF. (Reference approach methodology is detailed in Annex 4.)

A direct comparison of the reference approach and the sectoral approach used in the CRF shows a reference approach total that is consistently larger than the sectoral approach total. The predefined comparisons used in the CRF on Table 1-A(c) are not appropriate for Canada, since they are not comparing similar emission universes. The reference approach, in theory, includes all CO_2 emissions from all fossil fuel uses (combustion and process) in a country and should be compared only with a similar set of emissions from the sectoral approach. In the CRF, the reference approach is directly compared with the sectoral fuel combustion total. This comparison produces a significant discrepancy, since the sectoral approach total does not include fossil fuel-derived CO_2 from industrial processes. In Canada, a significant amount of fossil fuel is used for feedstocks in industrial processes, such as aluminium, ammonia, and ethylene production. The emissions resulting from these processes are reported as industrial processes. The Canadian reporting procedure does follow the IPCC guidelines (IPCC/OECD/IEA, 1997). When the comparison is corrected by adding the relevant industrial process data to the sectoral approach, the totals match within -5.6% to 4.4%. A reconciliation of the reference and sectoral approaches is shown in Table 3-8.

The activity data used in the sectoral approach and the reference approach are from the same published source. Statistics Canada compiles and publishes a national energy balance. This report compares energy production and supply with energy demand data at a sectoral level. One of the QA/QC procedures used by Statistics Canada to develop the energy data is to ensure that sectoral energy supply equals sectoral energy demand. As a result, the reference approach does not provide a useful tool for Canada in verifying the consistency of sectoral activity data.

In Canada, like the United States, gross heating value (GHV) is used to record the energy content of fuels, and this has been used throughout the sectoral approach to give an indication of fuel combustion activity in a particular sector.

TABLE 3-8: Reconciliation of Reference Approach and Sectoral Approach

kt CO_2 eq[1]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Ammonia Production	5 000	4 900	5 100	5 700	5 800	6 500	6 500	6 700	6 600	6 800	6 800	5 900	6 200	6 200
Iron and Steel Production	7 060	8 320	8 500	8 180	7 540	7 880	7 740	7 550	7 690	7 890	7 890	7 280	7 110	7 040
Aluminium Production	2 640	2 970	3 200	3 760	3 730	3 570	3 790	3 840	3 870	3 930	3 900	4 200	4 420	4 580
Other & Undifferentiated Production	9 200	9 600	9 000	9 700	11 000	10 000	11 000	11 000	11 000	12 000	12 000	13 000	13 000	14 000
Total Adjustment Value — Industrial Processes	24 000	26 000	26 000	27 000	28 000	28 000	29 000	30 000	30 000	30 000	30 000	30 000	30 100	32 000
Sectoral Approach Value	418 000	408 000	422 000	419 000	432 000	443 000	454 000	465 000	474 000	488 000	511 000	505 000	513 000	530 000
Reference Approach Total	444 000	447 000	462 000	466 000	475 000	485 000	504 000	508 000	513 000	514 000	533 000	530 000	513 000	549 000
Difference	6.19%	9.40%	9.40%	11.22%	9.96%	9.41%	10.85%	9.31%	8.19%	5.29%	4.29%	4.89%	0.05%	3.55%
Adjusted Sectoral Approach	442 000	434 000	448 000	446 000	460 000	471 000	484 000	495 000	504 000	519 000	542 000	535 000	543 000	562 000
Adjusted Difference	0.44%	2.89%	3.10%	4.41%	3.36%	2.88%	4.12%	2.78%	1.84%	-0.90%	-1.57%	-1.01%	-5.57%	-2.26%

Note:

1 Unless otherwise specified.

In previous years, Canada's reference approach was done in net heating value (NHV), since there were no readily available GHV-based emission factors for some of the raw fuels. As requested by the UNFCCC and to ease the comparison between the reference and the sectoral approaches, the reference approach this year is based on GHV. To do so, Canada developed country-specific energy conversion factors and carbon emission factors for the majority of the raw fuels except for crude oil, bitumen, solid biomass, and liquid biomass, where default IPCC carbon emission factors were used and converted to GHV using the Organisation for Economic Co-operation and Development (OECD) conversion factor of 95% for solid and liquid fuels.

The default factors provide a wide range of values, which can have an impact on the emission total. For example, crude oil has two NHV-based default factors listed — 20 or 21 tonnes of carbon per terajoule (t C/TJ). This difference alone can vary the reference approach total by 2%. For this method to provide consistent results, Canada needs to develop a method to estimate country-specific carbon emission factors for crude oil, bitumen, and solid and liquid biomass. This would improve the usefulness and accuracy of the reference approach.

To elaborate on the method of developing GHV conversion factors, a table has been included (Table 3-9) to illustrate the method and data sources used within the submission's reference approach. The energy conversion factors are taken directly from the RESD (Statistics Canada, #57-003), except for NGLs, LPG, and other bituminous coal, where the factors are based upon the proportion of their components.

The issue of aligning the NHV output of the reference approach to the GHV output of the national approach has been addressed this year. Some country-specific carbon emission factors are still not available but will be addressed in the coming cycle for completeness.

3.4.2 FEEDSTOCKS AND NON-ENERGY USE OF FUELS

Emissions from fuel use in the Energy Sector are those related to the combustion of the fuels for the purpose of generating heat or work. In addition to being combusted for energy production, fossil fuels are also consumed for non-energy purposes. Non-energy uses of fossil fuels include application as waxes, solvents, lubricants, and feedstocks (including the manufacturing of fertilizers, rubber, plastics, and synthetic fibres). Emissions from the non-energy use of fossil fuels have been included in the Industrial Processes Sector.

A discussion of the non-energy use of fossil fuels and the methodological issues associated with calculating emissions from this source may be found in Section 4.10.

3.4.3 CO_2 CAPTURE AND STORAGE

CO_2 is used in the Canadian petroleum industry as a means of enhancing oil recovery from depleted oil reservoirs. It is also disposed of with hydrogen sulphide in geologic reservoirs as part of some gas processing operations. Significant quantities of CO_2 releases are avoided through both of these activities; however, the quantities are not known or accounted for in the inventory (imported CO_2 used to enhance oil recovery is also not accounted for). All current inventory estimates assume that CO_2 originating from Canadian energy combustion sources is ultimately released to the atmosphere.

TABLE 3-9: Reference Approach Conversion Factors

Fuel Types			Energy Conversion Factor - GHV			Carbon Emission Factor - GHV (t C/TJ)		
			2003 Value	Unit	Reference	2003 Value	Derivation	Reference
Liquid Fossil	Primary Fuels	Crude Oil	39.22	TJ/ML	Ref. 4	19.00	20.00 × 95%	Ref. 1
		Orimulsion	N/A	–	–	N/A	–	–
		Natural Gas Liquids	20.01 *	TJ/ML	Ref. 4	16.02 *	–	Ref. 2
	Secondary Fuels	Gasoline	35.00	TJ/1000 m^3	Ref. 4	18.63	–	Ref. 2
		Jet Kerosene	37.40	TJ/1000 m^3	Ref. 4	18.68	–	Ref. 2
		Other Kerosene	37.68	TJ/1000 m^3	Ref. 4	18.45	–	Ref. 3
		Shale Oil	N/A	–	–	N/A	–	–
		Gas/Diesel Oil	38.30	TJ/1000 m^3	Ref. 4	19.15	–	Ref. 2
		Residual Fuel Oil	42.50	TJ/1000 m^3	Ref. 4	20.25	–	Ref. 2
		LPG	26.45 **	TJ/1000 m^3	Ref. 4	16.49 **	–	Ref. 2
		Ethane	17.22	TJ/1000 m^3	Ref. 4	15.61	–	Ref. 2
		Naphtha	35.17	TJ/1000 m^3	Ref. 4	19.33	–	Ref. 3
		Bitumen	44.46	TJ/1000 m^3	Ref. 4	20.90	22.00 × 95%	Ref. 1
		Lubricants	39.16	TJ/1000 m^3	Ref. 4	19.66	–	Ref. 3
		Petroleum Coke	40.57	TJ/1000 m^3	Ref. 4	24.76	–	Ref. 2
		Refinery Feedstocks	35.17	TJ/1000 m^3	Ref. 4	19.33	–	Ref. 3
		Other Oil	39.82	TJ/1000 m^3	Ref. 4	19.84	–	Ref. 3
Solid Fossil	Primary Fuels	Anthracite	27.70	TJ/kt	Ref. 4	26.76	–	Ref. 2
		Coking Coal	N/A	–	–	N/A	–	–
		Other Bituminous Coal	25.95 ***	TJ/kt	Ref. 4	22.31 ****	–	Ref. 2
		Sub-Bituminous Coal	19.15	TJ/kt	Ref. 4	24.95 ****	–	Ref. 2
		Lignite	15.00	TJ/kt	Ref. 4	25.73	–	Ref. 2
		Shale Oil	N/A	–	–	N/A	–	–
		Peat	N/A	–	–	N/A	–	–
	Secondary Fuels	BKB & Patent Fuel	N/A	–	–	N/A	–	–
		Coke Oven/Gas Coke	28.83	TJ/kt	Ref. 4	23.45	–	Ref. 3
Gaseous Fossil		Natural Gas	38.20	TJ/GL	Ref. 4	14.55	–	Ref. 2
Biomass		Solid Biomass	18.00	TJ/kt	Ref. 4	28.41	29.90 × 95%	Ref. 1
		Liquid Biomass	14.00	TJ/kt	Ref. 4	19.00	20.00 × 95%	Ref. 1
		Gas Biomass	N/A	–	–	N/A	–	–

References:

1 IPCC/OECD/IEA (1997).

2 McCann (2000).

3 Jaques (1992).

4 Statistics Canada (2003).

Notes:

* Composite value is based upon proportions of propane, butane, and ethane in Canada for the specific inventory year.

** Composite value is based upon proportions of refinery propane and butane in Canada for the specific inventory year.

*** Composite value is based upon provincial proportions for the specific inventory year.

**** Composite value is based upon proportions of production and imports in Canada for the specific inventory year.

N/A = not applicable; BKB = charcoal briquettes; GHV = gross heating value

3.4.4 COUNTRY-SPECIFIC ISSUES — EMISSIONS ASSOCIATED WITH THE EXPORT OF FOSSIL FUELS

Canada exports a great deal of its produced fossil resources, mostly to the United States. In 2003, Canada exported over 60% (energy equivalent) of its gross natural gas and crude oil production. The GHGs associated with this production have historically been estimated using a 1997 Environment Canada study as the basis. *Fossil Fuel Energy Trade & Greenhouse Gas Emissions*, prepared for Environment Canada by T.J. McCann and Associates (McCann, 1997), integrates the authors' expert perspective and national energy data to achieve a reasonable estimate of GHG emissions associated with natural gas and crude oil production in Canada for the years 1990–1995.

To update this work, 1996–2003 emission estimates have been calculated using similar energy data from Statistics Canada, while emissions attributable to the net exports were extrapolated based on the study. Using the emission results presented in the study, an empirical relationship was established between those emissions and the net exported energy associated with the volumes of crude oil and natural gas, as recorded by Statistics Canada. This trend was then applied to the actual 1996–2003 net exports to develop the emission estimates. Results are reported in the Executive Summary.

The emissions/sectors included within the two main fuel stream estimates are:

- *Natural Gas*: This category accounts for GHG emissions specific to the production, gathering, processing, and transmission of natural gas. It includes emissions from gas conservation systems at oil batteries (i.e., dehydrators, compressors, and related piping) and excludes emissions that may be attributed to the handling, processing (e.g., stabilization, treating, and/or fractionation), or storage of NGLs at gas facilities. Basically, only those sources that exist for the primary purpose of producing natural gas for sale are considered. Gas distribution systems and end-use emissions are specifically excluded, since they pertain to domestic gas consumption rather than gas imports and exports.
- *Crude Oil*: Similarly, this category considers emissions related to the production, treatment, storage, and transport of crude oils. Emissions from venting and flaring of associated or solution gas at these facilities are allocated to this category. Any gas equipment that is dedicated to servicing on-site fuel needs is part of the oil system. Gas conservation systems that produce into gas gathering systems are allocated to the natural gas system.

It must be noted that the absolute emission estimates provided here have a high level of uncertainty, as great as 40% or more. On the other hand, the trend estimates are more accurate and can be considered to be representative.

4 INDUSTRIAL PROCESSES (CRF SECTOR 2)

The Industrial Processes Sector includes emissions of all GHGs produced as a direct by-product of non-energy-related industrial activities. GHG emissions from fuel combustion for supplying energy for industrial activities are assigned to the Energy Sector.

The processes addressed in this sector include production and use of mineral products, ammonia production, nitric acid production, adipic acid production, ferrous metal production, aluminium metal production, magnesium metal production and casting, production and consumption of halocarbons, production and consumption of SF_6, and other and undifferentiated production.

CO_2 emissions resulting from the use of fossil fuels as feedstocks for the production of any chemical products other than ammonia, nitric acid, and adipic acid are reported under other and undifferentiated production (Section 4.10).

Emissions of indirect GHGs and sulphur dioxide (SO_2) from activities including asphalt roofing, road paving with asphalt, pulp and paper production, and production of food and drink have not been estimated.

As shown in Table 4-1, the GHG emissions from the Industrial Processes Sector contributed 52 Mt to the 2003 national GHG inventory, as compared with 54.4 Mt in 1990. The 2003 emissions represent 7% of the total Canadian GHG emissions in 2003. The overall decrease in emissions of 4.4% (as compared with the 1990 level) in this sector can be explained by significant emission diminutions in three categories: adipic acid production (90%), magnesium production (22%), and aluminium production (18%). In the case of adipic acid production, the Invista Maitland plant has been using an emission abatement system since 1997. The emission decrease for magnesium production is due to the progressive replacement of SF_6 used as cover gas with alternatives and the shutdown of a plant. Aluminium producers have also tried to reduce PFC emissions by means of emission control technologies, while maintaining an increasing production volume. Although an overall emission decrease from the 1990 level is observed in 2003, some categories in the Industrial Processes Sector show an emission growth.

In the case of consumption of halocarbons, increasing HFC emissions are a result of augmented use of HFCs to replace CFCs. Cement production, ammonia production, and other and undifferentiated production also experienced emission increases of 22%, 23%, and 49%, respectively (as compared with the 1990 levels).

The overall emissions for the Industrial Processes Sector increased by 2% from 2002 to 2003. This augmentation is mainly due to an increase in the use of SF_6 in electrical equipment and use of fuels for non-energy purposes. Even though from 2002 to 2003 the overall emissions from industrial processes climbed, some categories, such as adipic acid and magnesium production, showed an emission decrease, for the same reasons as described above.

TABLE 4-1: **Industrial Processes Sector GHG Emission Summary for Selected Years**

kt CO_2 eq

GHG Source Category	1990	2002	2003
Industrial Processes TOTAL	**54 400**	**51 000**	**52 000**
a. Mineral Production and Use	**7 800**	**8 600**	**8 700**
Cement Production	5 600	6 700	6 800
Lime Production	2 000	2 000	2 000
Limestone Use	370	160	160
Soda Ash Use	74	77	77
b. Chemical Industry	**17 000**	**8 300**	**8 100**
Ammonia Production	5 000	6 200	6 200
Nitric Acid Production	780	810	810
Adipic Acid Production	10 700	1 250	1 090
c. Metal Production	**19 100**	**17 100**	**16 800**
Iron and Steel Production	7 060	7 100	7 040
Aluminium Production	8 930	7 100	7 320
Magnesium Production	2 870	2 680	2 230
Magnesium Casting	237	233	247
d. Consumption of Halocarbons	**0**	**3 100**	**3 100**
e. SF_6 Use in Electrical Equipment	**1 800**	**1 000**	**1 600**
f. Other and Undifferentiated Production	**9 200**	**13 000**	**14 000**

Uncertainties associated with emission estimates for the Industrial Processes Sector were assessed in a study conducted by ICF Consulting (ICF, 2004). Although the study was prepared based on the 2001 inventory submitted in 2003, these uncertainty values are generally applicable to the 2003 estimates shown in this inventory, unless otherwise specified. The uncertainty in the total GHG emissions from this sector, with the exception of halocarbon consumption, for 2001 was estimated to be within the range of -7% to 5%. Provided that improvements have been made to some categories since the 2003 submission, this corresponds to a conservative uncertainty value for the current emission estimates. The uncertainties associated with the 2001 HFC and PFC emissions from consumption of halocarbons were evaluated at -20% to 55% and -28% to 70%, respectively. These also represent conservative uncertainty estimates for the 2003 numbers (see Section 4.8.3 for details). Details on the uncertainty values for each category are discussed throughout Chapter 4.

To ensure that the inventory was correctly prepared, the key categories of this sector (Cement Production, Ammonia Production, Adipic Acid Production, Iron and Steel Production, Aluminium Production, Magnesium Production, Consumption of Halocarbons, and Other and Undifferentiated Production) have all undergone Tier 1-level QC checks. It is important to note that the Tier 1 QC procedures have been carried out and documented by staff of the GHG Division not originally involved in the subject work. Details on the QA/QC plan for the national inventory as a whole and QC procedures can be found in Annex 6. For non-key categories, informal QC measures, such as double-checking calculations and checking activity data and emissions against the ones of previous years, have been taken.

4.1 MINERAL PRODUCTION AND USE (CRF CATEGORY 2.A)

4.1.1 SOURCE CATEGORY DESCRIPTION

This sector comprises emissions related to the production and use of non-metallic minerals, including cement, lime, limestone, and soda ash. Possible emissions of GHGs associated with the production and/or use of other mineral products have not been estimated.

4.1.1.1 Cement Production (CRF Category 2.A.1)

CO_2 is generated during the production of clinker, an intermediate product from which cement is made. Calcium carbonate ($CaCO_3$) from limestone, chalk, or other calcium-rich materials is heated in a high-temperature kiln, forming lime (CaO) and CO_2 in a process called calcination or calcining:

$CaCO_3 + \text{heat} \rightarrow CaO + CO_2$

The lime is then combined with silica-containing materials to produce clinker (greyish-black pellets about the size of 12-mm-diameter marbles). The clinker is removed from the kiln, cooled, and pulverized, and gypsum is added to produce portland cement. Almost all of the cement produced in Canada is of the portland cement type (ORTECH Corporation, 1994), which contains 60–67% lime by weight. Other specialty cements are lower in lime, but are typically used in small quantities.

CO_2 emissions from cement production are essentially directly proportional to lime content. The emissions resulting from the combustion of fossil fuels to generate the heat to drive the reaction in the kiln fall under the Energy Sector and are not considered here.

4.1.1.2 Lime Production (CRF Category 2.A.2)

Calcined limestone (quicklime or CaO) is formed by heating limestone to decompose carbonates. As with cement production, this is usually done at high temperatures in a rotary kiln, and the calcination process releases CO_2. Primarily high-calcium limestone (calcite) is processed in this manner from quarried limestone to produce quicklime in accordance with the same reaction discussed in Section 4.1.1.1 on cement production.

Dolomitic limestone (or magnesite) may also be processed at high temperature to obtain dolomitic lime (and release CO_2) in accordance with the following reaction:

$CaCO_3 * MgCO_3 \text{ (dolomite)} + \text{heat} \rightarrow CaO * MgO \text{ (dolomitic lime)} + 2CO_2$

Emissions from the regeneration of lime from spent pulping liquors at pulp mills are not accounted for in the Industrial Processes Sector. Since this CO_2 is biogenic in origin, it is recorded as a change in forest stock in the LULUCF Sector.

4.1.1.3 Limestone and Dolomite Use (CRF Category 2.A.3)

Limestone is a basic raw material used in a number of industries. In addition to its consumption in the production of cement and lime for resale, there are two other processes requiring significant amounts of the material: metallurgical smelting and glass making.

These industries use limestone at high temperatures. Therefore, the limestone is calcined to lime, producing CO_2 by the same reaction described in Section 4.1.1.1 on cement production.

4.1.1.4 Soda Ash Production and Use (CRF Category 2.A.4)

Soda ash (sodium carbonate, Na_2CO_3) is a white crystalline solid that is used as a raw material in a large number of industries, including glass manufacture, soap and detergents, pulp and paper manufacture, and water treatment (EIA, 1994). Based on use data supplied in the *Non-Metallic Mineral Products Industries* (Statistics Canada, #44-250) publication, it appears that soda ash in Canada is mainly used in the glass products manufacturing industry. CO_2 is emitted as the soda ash decomposes at high temperatures in a glass manufacturing furnace.

CO_2 may also be emitted during soda ash production, depending on the production process employed. CO_2 is generated as a by-product during production, but is usually recovered and recycled for use in the carbonation stage. According to Canadian industry, there are no emissions associated with the production of soda ash in Canada (General Chemical Canada Inc., personal communication, 1995).

4.1.2 METHODOLOGICAL ISSUES

4.1.2.1 Cement Production (CRF Category 2.A.1)

To estimate CO_2 emissions from cement production, Equation 3.1 of IPCC Good Practice Guidance (IPCC, 2000), as shown below, was used:

CO_2 emissions = $EF_{clinker}$ * Clinker Production * CKD Correction Factor

where:

$EF_{clinker}$ = emission factor based on clinker production

Clinker Production = clinker production data

CKD Correction Factor = factor that corrects for the loss of cement kiln dust (CKD)

The IPCC default $EF_{clinker}$ of 0.507 t CO_2/t clinker produced was applied. This factor was developed based on an average lime percentage of 64.6% and the molecular weight ratio of CO_2 to CaO in the raw material, which is 0.785 (IPCC/OECD/IEA, 1997). IPCC Good Practice Guidance suggests 1.02 (i.e., to add 2% to the CO_2 calculated for clinker) as the default CKD Correction Factor.

Clinker production data for 1997–2003 were obtained from Statistics Canada (#44-001). Applying the equation to these data is considered a Tier 2-type approach. Since clinker production data for 1990–1996 were not available from this latter publication and in order to reference the same source of cement data as much as possible for all historical years, the clinker production was estimated from the cement production data, as follows:

Estimated Clinker Production = (Portland Cement Production * Clinker Fraction in Portland Cement)
+ (Masonry Cement Production * Clinker Fraction in Masonry Cement)
− Imported Clinker
+ Exported Clinker

Data on portland and masonry cement production were obtained from Statistics Canada (#44-001). The values for clinker fractions of 96% and 64% for portland cement and masonry cement, respectively, are IPCC default values (IPCC, 2000). Data on imported and exported clinkers were obtained from the *Canadian Minerals Yearbook* (NRCan). Once estimates of clinker production for 1990–1996 were derived, CO_2 emissions were calculated using Equation 3.1 of IPCC Good Practice Guidance (IPCC, 2000), as shown above.

Data on clinker capacity of cement plants across Canada also came from the *Canadian Minerals Yearbook* (NRCan). These data were used to derive the percentage of total national clinker capacity attributed to each province/territory. CO_2 emissions on a provincial/territorial level were estimated by multiplying the percentage attributed to each province/territory by the national emission estimate.

4.1.2.2 Lime Production (CRF Category 2.A.2)

CO_2 emissions from lime production were estimated using an emission factor of 750 g CO_2/kg high-calcium lime (or quicklime) and an emission factor of 860 g CO_2/kg dolomitic lime. These IPCC default emission factors are based on the associated calcination reaction stoichiometry and IPCC default values for the lime content of the two types of lime (IPCC, 2000).

Total lime production and lime plant calcining capacity data were obtained from the *Canadian Minerals Yearbook* (NRCan). For any given year, the most recent lime production numbers provided are preliminary and are subject to revision in subsequent publications. The lime production data were corrected for the proportion of hydrated lime, using national hydrated lime production data and the IPCC default water content of 28% (IPCC, 2000). Furthermore, the IPCC default ratio of high-calcium lime to dolomitic lime, 85/15, was applied to the lime production data to estimate the quantity of each type of lime. National CO_2 emissions were calculated by applying the above-noted emission factors to the estimated yearly national lime production data, by lime type.

Data on calcining capacities of lime production facilities across Canada also came from the *Canadian Minerals Yearbook* (NRCan). These data were used to derive the percentage of total national calcining capacity attributed to each province/territory. It should be noted that the same 85/15 split was applied to the calcining capacities of those facilities known to produce both lime types. CO_2 emissions on a provincial/territorial level were estimated by multiplying the percentage attributed to each province/territory by the national emission estimate.

Since this estimation technique accounts for hydrated lime and the production of different lime types, it is considered to be an improved Tier 1-type methodology.

4.1.2.3 Limestone and Dolomite Use (CRF Category 2.A.3)

A (non-dolomitic) limestone use emission factor of 440 g CO_2/kg of limestone used was developed (ORTECH Corporation, 1994) using the chemical process stoichiometry. No data were available on the fraction of limestone used that is dolomitic. Thus, it was assumed that all lime is produced from high-calcium limestone.

Raw limestone consumption data by the glass and metallurgical smelting industries were obtained from the *Canadian Minerals Yearbook* (NRCan). The most recent limestone use data published were for 2002; therefore, it was assumed that there was no change in limestone use from 2002 to 2003. National CO_2 emissions were estimated by applying the emission factor to the yearly national limestone consumption data. An appropriate method for estimating limestone use emissions on a provincial/territorial basis has not yet been developed.

This technique is considered to be a Tier 1-type method, as it is based on the use of national consumption data and an average national emission factor. Methodological issues for calculating CO_2 emissions from limestone and dolomite use are not addressed specifically in the IPCC Good Practice Guidance (IPCC, 2000).

4.1.2.4 Soda Ash Production and Use (CRF Category 2.A.4)

For each mole of soda ash used, 1 mol of CO_2 is emitted. National CO_2 emissions were estimated by applying the emission factor of 415 g CO_2/kg of soda ash used to the national data on soda ash consumption in the glass product manufacturing industry. The emission factor (EF) for the mass of CO_2 emitted can be estimated from the stoichiometry of the chemical process as follows:

$$EF = (1000\ g/kg) * (44.01\ g\ CO_2/mol) / (105.99\ g\ Na_2CO_3/mol)$$
$$= 415\ g\ CO_2/kg\ Na_2CO_3$$

Data on soda ash use in glass manufacturing and in non-metallic mineral products industries were found in the *Non-Metallic Mineral Products Industries* (Statistics Canada, #44-250) publication for the years 1989, 1994, and 1995. For 1990–1993, data on use of soda ash in the non-metallic mineral products industry as a whole were published, but information on glass manufacturing was suppressed due to confidentiality. Based on 1989 and 1994 data, a linear relationship between the quantity of soda ash used in glass production and that in the entire non-metallic mineral products industry was developed. This correlation was then applied to estimate the quantities of soda ash used in glass manufacturing during 1990–1993. Since Statistics Canada publication #44-250 no longer includes information on soda ash use as a result of a format change in 1996, emissions have been assumed to stay constant at the 1995 level for 1996 onwards.

CO_2 emissions at a national level were estimated as described above. An appropriate method for estimating soda ash use emissions on a provincial/territorial basis has not yet been developed.

This technique is considered to be a Tier 1-type method, as it is based on the use of national consumption data and an average national emission factor. Methodological issues for calculating CO_2 emissions from soda ash use are not addressed specifically in the IPCC Good Practice Guidance (IPCC, 2000).

4.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

4.1.3.1 Cement Production

The uncertainty shown in the ICF (2004) report for the 2001 year estimate of this subsector is ±35%. This may represent a highly conservative uncertainty range for the 2003 estimate because there has been a methodological improvement since the last inventory. According to the IPCC Good Practice Guidance (IPCC, 2000), estimation via direct clinker production data, like in the case of the 2003 estimate, results in an error of about 10%. It should be recognized that this is an approximate IPCC default uncertainty value. A more complete and updated uncertainty assessment would be necessary to analyze in detail the uncertainty in the current emission estimate of this subsector.

Equation 3.1 of the IPCC Good Practice Guidance (IPCC, 2000) has been applied over the time series. Statistics Canada publication #44-001 was the source for 1997–2003 clinker production data. For 1990–1996, both publication #44-001 and the *Canadian Minerals Yearbook* (NRCan) were the sources for data needed to estimate clinker production. Clinker production capacity information for the time series was obtained from the *Canadian Minerals Yearbook*.

4.1.3.2 Lime Production

The ICF (2004) study shows an uncertainty range of -2% to 110% for the 2001 year emission estimate for lime production. The current emission estimation technique, which includes a correction factor for hydrated lime and accounts for different types of lime, makes the provided uncertainty highly conservative for the 2003 inventory estimate. However, the IPCC default ratio of high-calcium lime to dolomitic lime, 85/15, can be a source of uncertainty, since it may not be absolutely true in a Canadian context.

The data source and estimation technique used are consistent over the time series.

4.1.3.3 Limestone Use

The current inventory accounts only for emissions from the use of limestone in the glass industry and smelters. However, there may be other potential sources of CO_2 in which limestone is used (e.g., pulp and paper mills). Possible exclusion of sources where limestone is consumed and CO_2 is emitted results in an uncertainty of ±16% for the 2003 emission estimate of this category. It should be noted that the uncertainty value provided in the ICF report (ICF, 2004) is for the 2001 year estimate and is assumed to be applicable to the 2003 emission value, as there has not been any change in data source and methodology since the study was completed.

4.1.3.4 Soda Ash Use

Even though there has been an update to the time series due to the newly acquired 1994–1995 data, the lack of recent data (for the years after 1995) continues to contribute to the uncertainty of this category. Therefore, it is assumed that the uncertainty evaluated at -26% to 29% by ICF Consulting (ICF, 2004) is applicable to the 2003 inventory estimate.

The data source and emission factor used are consistent over the time series.

4.1.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

4.1.4.1 Cement Production

This key category in the Industrial Processes Sector has undergone for this submission Tier 1 QC checks as elaborated in the *Framework for a Quality Assurance and Quality Control Plan* (SNC Lavallin, 2004). The checks performed are consistent with the Tier 1 General Inventory Level QC Procedures outlined in the IPCC Good Practice Guidance (IPCC, 2000). No issues of importance were detected from the Tier 1 QC process.

4.1.4.2 Lime Production

Informal QC procedures have been performed. For example, the published lime production estimates have been compared with the published aggregate national plant calcining capacities to verify the reasonableness of the activity data.

4.1.4.3 Limestone and Soda Ash Use

Informal QC measures, such as double-checking calculations and checking activity data and emissions against the ones of previous years, have been taken.

4.1.5 CATEGORY-SPECIFIC RECALCULATIONS

4.1.5.1 Cement Production (CRF Category 2.A.1)

The 2002 CO_2 emissions from cement production at a provincial/territorial level were recalculated. This recalculation was due to the update of data on cement plant clinker capacity obtained from the *Canadian Minerals Yearbook* (NRCan).

4.1.5.2 Lime Production (CRF Category 2.A.2)

The 2002 CO_2 emissions from lime production at national and provincial/territorial levels were recalculated. This recalculation was due to the update of data on national lime production and national hydrated lime production obtained from the *Canadian Minerals Yearbook* (NRCan).

4.1.5.3 Limestone and Dolomite Use (CRF Category 2.A.3)

The 2003 edition of the *Canadian Minerals Yearbook* (NRCan) published limestone use data for 2002. The 2002 emissions for this sector, which were previously assumed equal to the 2001 emissions due to lack of data, have been recalculated. The reported limestone use for 2002 was less than the previously assumed estimate, resulting in a decrease in CO_2 emissions from limestone use in 2002.

4.1.5.4 Soda Ash Use (CRF Category 2.A.4.2)

In previous inventories, emissions for the years 1990–1993 were estimated by assuming a constant ratio (established based on 1989 data) between the consumption of soda ash in glass manufacturing and in the non-metallic minerals industry as a whole. Also, emissions for 1994 onwards were previously assumed to stay constant at the 1993 level. Based on some newly acquired data, namely those of the years 1994 and 1995, and the assumption that emissions from 1996 onwards stay constant at the 1995 level, the entire time series has been recalculated. Details on the current methodology are provided above.

4.1.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

4.1.6.1 Cement Production (CRF Category 2.A.1)

During the preparation of this inventory, it was noticed that significant differences exist between the cement production statistics found in Statistics Canada publication #44-001 and those in the *Canadian Minerals Yearbook* (NRCan). Therefore, an attempt will be made to resolve these differences.

4.1.6.2 Lime Production (CRF Category 2.A.2)

There are currently no improvements planned specifically for estimating CO_2 emissions from lime production.

4.1.6.3 Limestone and Dolomite Use (CRF Category 2.A.3)

Improvements in estimating CO_2 emissions from limestone use may comprise the inclusion of limestone use by the pulp and paper industry in the activity data and an investigation into the limestone use data published under the general heading "other chemical uses" in the *Canadian Minerals Yearbook* (NRCan) to determine what portion of these data, if any, should be added to the activity data.

4.1.6.4 Soda Ash Use (CRF Category 2.A.4.2)

Since Statistics Canada publication #44-250 no longer includes information on soda ash use, new potential sources of data will be examined to acquire recent soda ash use data at national and provincial/territorial levels.

4.2 AMMONIA PRODUCTION (CRF CATEGORY 2.B.1)

4.2.1 SOURCE CATEGORY DESCRIPTION

Most of the ammonia (NH_3) produced in Canada is manufactured using the Haber-Bosch process in which nitrogen and hydrogen react together. The hydrogen used usually comes from steam reformation of natural gas, which produces CO_2 as a by-product.

Fertilizer plants are often large producers of ammonia, since one of the main usages of ammonia is to manufacture fertilizing agents. CO_2 released from the production of ammonia may be used for making urea. However, since the carbon is released to the atmosphere upon the application of fertilizer to the soil and is trapped in urea for only a short time, no account is taken of intermediate binding of CO_2 in downstream manufacturing processes and products (IPCC/OECD/IEA, 1997).

4.2.2 METHODOLOGICAL ISSUES

Total ammonia production data were obtained from the publication *Industrial Chemicals and Synthetic Resins* (Statistics Canada, #46-002). Ammonia production plant capacities were obtained from the publication *Fertilizer Production Capacity Data — Canada* (CFI, 1999). Since some of the hydrogen produced for ammonia production was a by-product of other chemical processes (Jaques, 1992), thereby eliminating the release of CO_2 from the synthesis process, the gross ammonia production was reduced accordingly. National emissions were estimated by multiplying the net ammonia production by an emission factor of 1.56 t CO_2/t NH_3 produced. This emission factor was developed using typical energy and material requirements for ammonia production in Canada (Jaques, 1992).

This technique is considered to be a Tier 1-type method, as it is based on the use of national production data and an average national emission factor. Methodological issues for calculating CO_2 emissions from ammonia production are not addressed specifically in the IPCC Good Practice Guidance (IPCC, 2000).

It should be noted that the quantity of natural gas used to produce hydrogen for ammonia production was also recorded by Statistics Canada with all other non-energy uses of natural gas. Therefore, to avoid double-counting, the CO_2 emissions from ammonia production were subtracted from the total non-energy fossil fuel use CO_2 emissions.

4.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty in the CO_2 emission estimates for ammonia production is estimated to be -23% to 55%. This uncertainty range provided in the ICF report (ICF, 2004) is applicable to the 2003 estimate because the current methodology and data source are the same as the ones used for the 2001 inventory. The emission factor is responsible for most of the uncertainty in this category. The portion of ammonia production attributed to hydrogen produced as a chemical process by-product, which is assumed to be constant for the whole time series, is another contributing factor. An additional source of uncertainty would be the amount of CO_2 trapped in exported products such as urea, which is currently not accounted for in the inventory. A sensitivity analysis is being conducted to determine the relative contribution of the activity data and emission factor to the uncertainty associated with this category.

The data sources and methodology used are consistent over the time series.

4.2.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

Ammonia Production is a key category that has undergone for this submission Tier 1 QC checks as elaborated in the *Framework for a Quality Assurance and Quality Control Plan* (SNC Lavallin, 2004). The checks performed are consistent with the Tier 1 General Inventory Level QC Procedures outlined in the IPCC Good Practice Guidance (IPCC, 2000). No issues of importance were detected from the Tier 1 QC process.

4.2.5 CATEGORY-SPECIFIC RECALCULATIONS

There have been no recalculations of CO_2 emissions related to ammonia production.

4.2.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

As previously mentioned, urea production consumes much of the CO_2 that would otherwise be released to the atmosphere during ammonia manufacture. Since a significant quantity of urea produced in Canada is exported and CO_2 trapped in urea will be released only upon its application, efforts will be made to determine the quantity of CO_2 in exported urea. Also, an attempt will be made to update the quantity of ammonia production for which the hydrogen used is a by-product of chemical processes and which, therefore, does not involve any CO_2 emissions.

4.3 NITRIC ACID PRODUCTION (CRF CATEGORY 2.B.2)

4.3.1 SOURCE CATEGORY DESCRIPTION

Nitric acid (HNO_3) is an inorganic compound used primarily in the production of synthetic commercial fertilizers. It may also be used for producing explosives and other chemicals, such as adipic acid. Since nitric acid is produced from ammonia, N_2O is emitted. The quantity of N_2O released is proportional to the amount of ammonia used. The concentration of N_2O in the exhaust gases depends on the type of plant and its emission controls.

4.3.2 METHODOLOGICAL ISSUES

Canada-specific emission factors were developed based on the type of abatement technology that is employed at individual plants.

One of the first attempts to estimate emissions of N_2O for this sector used information provided by the global industry, which was based on company-specific measurements and calculations (McCulloch, 1991; Norsk Hydro, 1991). These estimates reported emissions ranging from 2 to 20 kg N_2O/t NH_3 consumed in the production of nitric acid. However, subsequent investigations indicated that emissions from Canadian plants were at the low end of this range. As a result, the following emission factors (EF) were developed (Collis, 1992):

- plants with catalytic converters: EF = 0.66 kg N_2O/t HNO_3 produced;
- plants with extended absorption for NO_x abatement type 1: EF = 9.4 kg N_2O/t HNO_3 produced; and
- plants with extended absorption for NO_x abatement type 2: EF = 12 kg N_2O/t HNO_3 produced.

Annual national nitric acid production data were obtained from the publication *Industrial Chemicals and Synthetic Resins* (Statistics Canada, #46-002).

All nitric acid plants in Canada, with the exception of those in Alberta, are of the catalytic converter type. For Alberta, it has been assumed that 175 kt HNO_3 are produced by plants with extended type 1 and 30 kt HNO_3 are produced by plants with extended type 2. The remainder are from catalytic converter-type plants. Nitric acid plant capacity data are subsequently used to estimate N_2O emissions on a provincial/territorial basis.

This technique is considered to be a Tier 2-type method, as it is based on abatement-specific emission factors. The emission factors are within the range published by IPCC/OECD/IEA (1997).

4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The N_2O emission estimate for nitric acid production has an uncertainty of -15% to 16%. The uncertainty range provided in the ICF report (ICF, 2004) is applicable to the 2003 inventory because the current methodology and data source are the same as the ones used for the 2001 inventory. One possible source of uncertainty would be the emission factors, which may require an update. The assumption made for plants in Alberta, as mentioned above, may also bring about uncertainty in the N_2O emissions for this category. A sensitivity analysis is being performed to relate the uncertainty of this category to its input parameter uncertainties. The results will be discussed in the next NIR for Canada.

The data sources and methodology used are consistent over the time series.

4.3.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

Informal QC measures, such as double-checking calculations and checking emission estimates against the ones of previous years, have been taken. In addition, the published nitric acid production estimates are compared with the aggregate national nitric acid plant capacities to determine the reasonableness of the activity data.

4.3.5 CATEGORY-SPECIFIC RECALCULATIONS

There have been no recalculations of N_2O emissions related to nitric acid production.

4.3.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

Improvements to the N_2O emissions methodology in accordance with the IPCC Good Practice Guidance (IPCC, 2000) are being considered. The possibility of incorporating N_2O destruction factors and abatement system utilization factors into the emissions calculations will be investigated.

4.4 ADIPIC ACID PRODUCTION (CRF CATEGORY 2.B.3)

4.4.1 SOURCE CATEGORY DESCRIPTION

Adipic acid is a dicarboxylic acid produced via a two-stage oxidation process and used primarily in the production of Nylon 66. N_2O is generated as a by-product of the second oxidation stage and is generally vented to the atmosphere in a waste gas stream.

The only adipic acid production facility in Canada is operated by Invista (formerly DuPont) and located in Maitland, Ontario. An emission abatement system was installed at the facility in 1997, for which Invista implemented a program of emissions monitoring to determine the performance efficiency of the abatement system.

4.4.2 METHODOLOGICAL ISSUES

The emission estimates for adipic acid production were provided by the Invista Maitland plant. For the period of 1990–1996, when no emission controls were in place, the reported emission estimates were calculated by multiplying adipic acid production by an emission factor of 0.303 kg N_2O/kg adipic acid. From 1997 to 2003, the reported emission data came from direct monitoring.

This technique is considered to be a Tier 3-type method, as it is based on the reported facility-specific emission data.

4.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

According to the ICF (2004) report, the 2001 N_2O emission estimate for adipic acid production had an uncertainty of ±2%, reflecting the random component of the uncertainty related to monitoring and reporting of emissions. The provided uncertainty value is applicable to the 2003 estimate of this category.

The data source remains consistent over the time series, but the methodology has evolved, as previously mentioned. Prior to 1997, N_2O emissions from adipic acid production were estimated by Invista based on production, whereas emissions reported from 1997 to the present are directly measured using emissions monitoring equipment.

4.4.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

Adipic Acid Production is a key category that has undergone for this submission Tier 1 QC checks as elaborated in the *Framework for a Quality Assurance and Quality Control Plan* (SNC Lavallin, 2004). The checks performed are consistent with the Tier 1 General Inventory Level QC Procedures outlined in the IPCC Good Practice Guidance (IPCC, 2000). No issues of importance were detected from the Tier 1 QC process.

4.4.5 CATEGORY-SPECIFIC RECALCULATIONS

There have been no recalculations of N_2O emissions related to adipic acid production.

4.4.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

There are currently no improvements planned specifically for estimating N_2O emissions from adipic acid production in Canada. However, efforts will be made to obtain additional information on the abatement technology employed, the N_2O monitoring system, and the accuracies involved. Also, as suggested in the UNFCCC review, an attempt will be made to acquire historical production data.

4.5 IRON AND STEEL PRODUCTION (CRF CATEGORY 2.C.1)

4.5.1 SOURCE CATEGORY DESCRIPTION

Iron is produced through the reduction of iron oxide (ore) with metallurgical coke (as the reducing agent) in a blast furnace to produce pig iron. The metallurgical coke used in the furnace is oxidized in the process to CO_2 and emitted to the atmosphere. Some carbon is stored in the pig iron; however, this is mostly released to the atmosphere during the steel production process. Steel is made from pig iron and/or scrap steel using electric arc furnaces (EAFs), basic oxygen furnaces, or cupola furnaces.

The emission estimates in this category include emissions from the production of steel in EAFs or basic oxygen-type furnaces. These emissions are based on the difference between the carbon contents of iron and steel and the oxidation of fossil fuel carbon-based electrodes that occurs in EAFs. The emissions related to electrode consumption are subtracted from the emissions under the other industrial processes section of this chapter (Section 4.10) to avoid double-counting.

Emissions from the combustion of fuels such as coke oven gas are not reported in this category, but rather under the appropriate industrial category in the Energy Sector.

CO_2 emissions from the use of petroleum coke in the ferroalloy smelting process are included under other industrial processes (Section 4.10).

4.5.2 METHODOLOGICAL ISSUES

National CO_2 emissions from iron production were calculated by multiplying the mass of reducing agent used in the iron and steel industry by an emission factor for the reducing agent. It was assumed that 100% of the fuel used as a reducing agent is metallurgical coke, and the emission factor used for metallurgical coke as a reducing agent is 2.48 kg CO_2/kg metallurgical coke. These emissions also accounted for the difference between the carbon contents of the iron ore and the crude iron produced, and default carbon content values of 0% and 4% were used for iron ore and crude iron, respectively (IPCC, 2000).

As previously mentioned, emissions from steel production were included in the emission estimates. The difference between the carbon contents of the crude iron used in steel production and the steel produced was calculated using default values of 4% and 1.25% for the carbon contents of crude iron and crude steel, respectively (IPCC, 2000). Emissions from the consumption of carbon electrodes in EAFs were calculated by multiplying the mass of steel produced in EAFs by an emission factor of 4.58 kg CO_2/t of steel produced in EAFs. This emission factor was derived based on the IPCC default value for the mass of carbon released from consumed electrodes per tonne of steel (IPCC, 2000).

National and provincial/territorial metallurgical coke use data were obtained from the RESD (Statistics Canada, #57-003), as reported under iron and steel. Metallurgical coke data published for any given year are preliminary and subject to revision in subsequent publications. National data for total pig iron production, total pig iron charged to steel furnaces, total steel production, and steel produced in EAFs were obtained from the *Primary Iron and Steel* (Statistics Canada, #41-001) publication. The CO_2 emissions from iron and steel production at a provincial/territorial level were estimated based on the percentage of the national metallurgical coke use attributable to each province/territory.

This estimation technique is considered to be Tier 2-type, as the emission estimates are based on tracking carbon through the production process.

4.5.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty in the 2001 inventory's CO_2 emission estimate for iron and steel production is ±5% (ICF, 2004). It should be noted that this represents a conservative uncertainty value for the 2003 inventory emission estimates because the methodology for calculating CO_2 emissions has improved since the last inventory. The shift from a Tier 1 to Tier 2 approach is expected to lower the uncertainty. However, an updated analysis would be needed to fully assess the uncertainty in the estimates calculated using a Tier 2-type technique.

The data sources and methodology used are consistent over the time series.

4.5.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

Iron and Steel Production is a key category that has undergone for this submission Tier 1 QC checks as elaborated in the *Framework for a Quality Assurance and Quality Control Plan* (SNC Lavallin, 2004). The checks performed are consistent with the Tier 1 General Inventory Level QC Procedures outlined in the IPCC Good Practice Guidance (IPCC, 2000). No issues of importance were detected from the Tier 1 QC process.

4.5.5 CATEGORY-SPECIFIC RECALCULATIONS

The 2002 CO_2 emission estimates from iron and steel production have been recalculated due to acquisition of updated 2002 data on the consumption of metallurgical coke at national and provincial/territorial levels.

4.5.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

There are currently no improvements planned specifically for estimating CO_2 emissions from iron and steel production in Canada.

4.6 ALUMINIUM METAL PRODUCTION (CRF CATEGORY 2.C.3)

4.6.1 SOURCE CATEGORY DESCRIPTION

Primary aluminium is produced in two steps. First, bauxite ore is ground, purified, and calcined to produce alumina (Al_2O_3). Next, the alumina is electrically reduced to aluminium by smelting in large pots with carbon-based anodes. The pot itself (a shallow steel container) forms the cathode, while the anode consists of one or more carbon blocks suspended within it. Inside the pot, alumina is dissolved in a fluorine bath consisting primarily of cryolite (Na_3AlF_6). Passing a current through the resistance of the cell causes the heating effect, which maintains the contents in a liquid state. Molten aluminium is evolved while the anode is consumed in the reaction. The aluminium forms at the cathode and gathers on the bottom of the pot.

Three GHGs — CO_2, carbon tetrafluoride (CF_4), and carbon hexafluoride (C_2F_6) — are known to be emitted during the reduction process. CF_4 and C_2F_6 are part of a larger class of GHGs known as PFCs. PFCs are considered potent GHGs, as reflected by their high GWPs.

As the anode is consumed, CO_2 is formed in the following reaction, provided that enough alumina is present at the anode surface:

$$Al_2O_3 + \tfrac{3}{2}C \rightarrow 2Al + \tfrac{3}{2}CO_2$$

Most of the CO_2 forms from the reaction of the carbon anode with alumina, but some is formed as the anode reacts with other sources of oxygen (especially air). This occurs during cell operation and, in the case of pre-baked electrodes, during anode production and manufacture.

Aluminium plants are characterized by the type of anode technology employed. In general, older plants with Søderberg technology have higher emissions than newer plants, which usually use pre-baked anodes. The trend in the Canadian aluminium industry has been towards modernizing facilities, since production efficiency is improved. In some cases, this has meant taking old lines out of production as new ones are installed to meet increasing demand.

Primary aluminium smelting is the only known major source of PFCs (Jacobs, 1994). PFC gases are formed during an occurrence known as the anode effect or anode event, when alumina levels are low. If the concentration of alumina at the anode is reduced to below ~2% (by weight), an anode event may begin. In theory, when an anode event occurs, the cell resistance increases very suddenly (within a 50th of a second). As a result, the voltage rises and the temperature goes up, forcing the molten fluorine salts in the cell to chemically combine with the carbon anode (Laval University, 1994).

During the anode event, competing reactions occur to produce CO, CF_4, and C_2F_6, in addition to CO_2. The two reactions of interest at this point are:

$$Na_3AlF_6 + \tfrac{3}{4}C \rightarrow Al + 3NaF + \tfrac{3}{4}CF_4$$

$$Na_3AlF_6 + C \rightarrow Al + 3NaF + \tfrac{1}{2}C_2F_6$$

PFC emissions can be controlled by computerized alumina feeders. Sensors detect alumina concentration and automatically feed more to the pot when levels become low. In this way, anode events can be controlled. The computers can be programmed to detect the onset of anode events as well, providing additional warning for the system to take counteractive measures. "Point" feeders, as opposed to "centre-break" types, also tend to reduce emissions (Øye and Huglen, 1990).

Although aluminium production consumes extremely large quantities of electrical energy, currently estimated to be 13.5 kWh/kg of aluminium (AIA, 1993), GHG emissions associated with this consumption are not necessarily high. All of Canada's primary aluminium smelters are located in Quebec and British Columbia, where almost all (95%) of the electricity generated is produced by hydraulic generators; these are believed to emit a negligible amount of GHGs compared with conventional fossil fuel-based electricity generators.

4.6.2 METHODOLOGICAL ISSUES

Process-related emission estimates for aluminium production were directly obtained from the Aluminium Association of Canada (AAC), as opposed to previous reporting years, when emissions had been calculated by multiplying aluminium production data by cell technology-specific emission factors. These emissions were based on audited data that members of the AAC — namely, Alcan, Alcoa, and Aluminerie Alouette Inc. — have reported to the Government of Quebec under the Framework Agreement on Voluntary Greenhouse Gas Reductions in Quebec since 2002. Although emissions from Alcan's smelter at Kitimat, British Columbia, were not reported to the Government of Quebec, audited estimates of these emissions were provided to the GHG Division. In addition to the smelter-specific emission estimates, information on the methodologies used by the aluminium producers to calculate CO_2 and PFC emissions was obtained from the AAC. The estimation techniques applied may be Tier 3-, 2-, or 1-type, as described below, depending on data availability; a Tier 3-type technique has mostly been applied for estimating emissions for recent years.

Typically, the equations used by smelters to estimate CO_2 emissions from the reaction of the carbon anode with alumina are (AAC, 2002):

For Prebaked Anode Consumption:

E_{CO_2} (t) = [CC * MP * (100 - %S_a - %Ash_a - %Imp_a)/100] * 44/12

where:

CC = carbon consumption per tonne of aluminium (t C/t Al)
MP = total aluminium production (t)
S_a = sulphur content in baked anodes (wt%)
Ash_a = ash content in baked anodes (wt%)
Imp_a = fluorine and other impurities (wt%)*
44/12 = the ratio of the molecular weight of CO_2 to the molecular weight of C.

* The weight percentage of fluorine and other impurities may not be a parameter considered by all the smelters.

For Søderberg Anode Consumption:

E_{CO_2} (t) = [(PC * MP) - (BSM * MP/1000) - [%BC/100 * PC * MP * (%S_p + %Ash_p + [%H_2/100])] - [(100 - %BC)/100 * PC * MP * (%S_c + %Ash_c)/100]] * 44/12

where:

PC = paste consumption (t paste/t Al)
MP = total aluminium production (t)
BSM = emissions of benzene-soluble matter (kg/t Al)
BC = average binder content in paste (wt%)
S_p = sulphur content in pitch (wt%)
Ash_p = ash content in pitch (wt%)
H_2 = hydrogen content in pitch (wt%)
S_c = sulphur content in calcinated coke (wt%)
Ash_c = ash content in calcinated coke (wt%)
44/12 = the ratio of the molecular weight of CO_2 to the molecular weight of C.

The use of the equations above with actual process data to estimate CO_2 emissions is considered Tier 3-type methodology. A Tier 2-type technique involves the application of some measured data in combination with industrial typical values (as provided by AAC) to these equations.

When no process data other than aluminium production are available, emission factors for a Tier 1 method (as shown below) can be used. These factors depart slightly from the IPCC default ones. According to a supporting document provided by the AAC (2002), this is because the IPCC Tier 1 default factors reflect 1990 emissions and would produce considerable errors if applied to current production. The factors below reflect the considerable progress that has been made over the period from 1990 to 2001 (AAC, 2002):

- Søderberg: EF = 1.7 t CO_2/t Al produced; and
- Pre-baked: EF = 1.6 t CO_2/t Al produced.

CF_4 and C_2F_6 emitted during anode effects can be calculated by smelters using either the Slope or Pechiney Overvoltage Method, depending on the smelter technology (AAC, 2002):

Slope Method:

E_{PFC} (t CO_2) = slope * AEF * AED * MP * GWP / 1000

where:

slope = slope (for CF_4 or C_2F_6) of the emission relationship ([kg PFC/t Al]/[AE-minutes/cell-day])
AEF = number of anode effects per pot per day (AE/cell-day)
AED = anode effect duration (minutes)
MP = total aluminium production (t)
GWP = global warming potential for CF_4 or C_2F_6

Pechiney Overvoltage Method:

E_{PFC} (t CO_2) = overvoltage coefficient * AEO / CE * GWP * MP / 1000

where:

overvoltage coefficient = ([kg PFC/t Al]/[mV/cell-day])

AEO = anode effect overvoltage (mV/cell-day)

CE = aluminium production process current efficiency expressed as a fraction

GWP = global warming potential for CF_4 or C_2F_6

MP = total aluminium production (t)

The use of the equations above with actual process data to estimate PFC emissions is considered Tier 3-type methodology. The estimation technique is considered as Tier 2-type when default coefficients shown below in Table 4-2 are used together with smelter-specific operating parameters. Most of these coefficients are found in Table 3-9 of the IPCC Good Practice Guidance (IPCC, 2000). The overvoltage coefficients for C_2F_6, which are not provided by the IPCC Good Practice Guidance, can be estimated as either: A) 10% of that for CF_4 or B) the ratio of the slope coefficient for C_2F_6 to the one for CF_4, depending on the smelter (AAC, 2002).

TABLE 4-2: Default Slope and Overvoltage Coefficients

	Slope Coefficients ([kg PFC/t Al]/[AE-minutes/cell-day])		Overvoltage Coefficients ([kg PFC/t Al]/[mV/cell-day])		
	CF_4	C_2F_6	CF_4	C_2F_6	
Type of Cell				A	B
Centre Worked Pre-Baked	0.14	0.018	1.9	0.19	0.13
Side Worked Pre-Baked	0.29	0.029	1.9	0.19	0.10
Vertical Stud Søderberg	0.068	0.003	N/A	N/A	N/A
Horizontal Stud Søderberg	0.18	0.018	N/A	N/A	N/A

Note:
N/A = not applicable

If only production statistics are available (i.e., no data on anode effect frequency, anode effect duration, or anode effect overvoltage), the emission factors shown in Table 4-3 can be used by smelters (AAC, 2002).

TABLE 4-3: PFC Emission Factors

	Emission Factors (kg PFC/t Al)					
	1990–1993		1994–1997		1998–2000	
Type of Cell	CF_4	C_2F_6	CF_4	C_2F_6	CF_4	C_2F_6
Centre Worked Pre-Baked	0.4	0.068	0.3	0.051	0.2	0.034
Side Worked Pre-Baked	1.4	0.336	1.4	0.336	1.4	0.336
Vertical Stud Søderberg	0.6	0.036	0.5	0.03	0.4	0.024
Horizontal Stud Søderberg	0.7	0.063	0.6	0.054	0.6	0.054

CO_2 and PFC emission estimates for Alcan's smelters were not provided for the years 1991–1994 and 1996–1999 due to data unavailability. To estimate emissions from Alcan's smelters for these years, linear interpolation between the provided 1990 and 2003 data was applied.

It should be noted that the use of petroleum coke in anodes for the production of aluminium was also reported by Statistics Canada with all other non-energy uses of petroleum coke. The CO_2 emissions from the consumption of anodes in the aluminium smelting process were therefore subtracted from the total non-energy emissions to avoid double-counting.

4.6.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainties in CO_2 and PFC emission estimates for aluminium production shown in the ICF report (ICF, 2004) are not applicable to the 2003 inventory year estimates due to the change in activity data. Audited emission data coming directly from the AAC are included in this year's (2003) inventory; these data are believed to be significantly more accurate than the previous estimates. An updated uncertainty analysis would be necessary in order to determine the range of uncertainty around the reported values (also see Planned Improvements).

The AAC has consistently been used as the data source of estimates shown in this inventory over the time series. The methodology applied by smelters may be Tier 3-, 2-, or 1-type, depending on data availability. However, for recent years, a Tier 3-type technique has been applied by all smelters for estimating emissions.

4.6.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

As part of the agreement with the Government of Quebec, the data reported by each aluminium producer to the Government of Quebec must be audited by an independent third party authorized by the Government of Quebec. Also, the audit firm should have an internal system of quality control. The audits performed ensure that the data used in the calculation of GHG emissions are free of errors and reflect actual conditions (AAC and Government of Quebec, 2003). The same sets of audited emission estimates and copies of the audit reports certified by the audit firm were provided by the AAC to the GHG Division for this submission. It should be noted that although emission estimates for Alcan's smelter at British Columbia have not been reported to the Government of Quebec, they have undergone the same auditing procedures as the estimates for the other Alcan smelters.

In addition to auditing, Aluminium Metal Production, like all other key categories, has gone through Tier 1 QC checks as elaborated in the *Framework for a Quality Assurance and Quality Control Plan* (SNC Lavallin, 2004). The checks performed are consistent with the Tier 1 General Inventory Level QC Procedures outlined in the IPCC Good Practice Guidance (IPCC, 2000). No issues of importance were detected from the Tier 1 QC process.

4.6.5 CATEGORY-SPECIFIC RECALCULATIONS

In previous inventories, estimates were computed based on prorated aluminium production data, which were derived from capacity data, and cell technology-specific emission factors. Based on some smelter-specific CO_2 and PFC emission estimates obtained from the AAC and the results from interpolation of the provided 1990 and 2003 estimates, the 1990–2002 emissions have been recalculated. The methodologies applied by smelters to estimate emissions as reported by the AAC are described above. The methodological change has resulted in a decrease of approximately -45% to -12% in the PFC emissions over the period 1990–2002. CO_2 emissions for the same period have also slightly varied (±1%) due to the change in methodology.

4.6.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

There are currently no improvements planned specifically for estimating CO_2 and PFC emissions from aluminium production in Canada. However, the possibility of including SF_6 emissions from aluminium production in the inventory will be investigated. An attempt to obtain, through expert elicitation, uncertainty values around the emission estimates provided by the AAC will also be made.

4.7 MAGNESIUM METAL PRODUCTION AND CASTING (CRF CATEGORY 2.C.4)

4.7.1 SOURCE CATEGORY DESCRIPTION

SF_6 is emitted during magnesium production and casting, where it is used as a cover gas to prevent oxidation of the molten metals. Although emitted in relatively small quantities, SF_6 is an extremely potent GHG, with a 100-year GWP of 23 900. SF_6 is not manufactured in Canada. All SF_6 is imported.

In 2003, there were three magnesium producers in Canada: Norsk Hydro, Timminco Metals, and Métallurgie Magnola Inc. Norsk Hydro has improved its production technologies to minimize the consumption of SF_6, while production has increased over the same period. Métallurgie Magnola has been shut down since April 2003.

According to a recent study that is to be completed (Cheminfo Services, 2005), there were 10 known magnesium casting facilities in operation during the period 1990–2003. Only one of them has used SF_6 every year during the entire period. Some casters started using SF_6 towards the mid- or late 1990s, while others have replaced it with an alternative gas such as SO_2. Two facilities have ceased their casting operations over the last few years.

4.7.2 METHODOLOGICAL ISSUES

For SF_6 emissions from magnesium production, data for 1999–2003 were directly reported by the companies (Norsk Hydro, Timminco Metals, and Métallurgie Magnola Inc.) through a mandatory emissions reporting program known as the National Pollutant Release Inventory (NPRI). For previous years, the data were provided voluntarily by telephone from the producers.

The technique applied to estimate emissions from magnesium production is considered to be a Tier 3-type method, as it is based on the reporting of facility-specific emission data.

For calculating SF_6 emissions, the IPCC guidelines (IPCC/OECD/IEA, 1997) provide one general equation that assumes that all SF_6 used as a cover gas is emitted to the atmosphere. To apply this equation, an attempt to collect data on SF_6 consumption from casting facilities has been made during the course of the study mentioned above. Although it was expected that completed questionnaires would be received from most casters before the end of this project, only a few responses have been received to date due to time constraints. A couple of facilities have also indicated that they do not hold any historical records of their past SF_6 consumption. Therefore, to estimate SF_6 use for all 10 casters, results of a previous study (Cheminfo Services, 2002) were used in combination with the data received to date for this recent study (Cheminfo Services, 2005). This is an interim methodology until more responses to the questionnaire can be gathered.

For casters that have SF_6 data for only a year, it was assumed that their SF_6 use stays constant, for the other operating years, at the level of the year for which there are actual SF_6 data. For casters that have data for more than one year, linear interpolation between two data points is applied to estimate SF_6 consumption for the other years.

The technique applied to estimate emissions from magnesium casting is considered to be a modified Tier 3-type method, as it is based on the reporting of facility-specific emission data and some assumptions.

4.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty in the 2001 SF_6 emission estimate for magnesium production, provided in the ICF (2004) report, was evaluated at ±1% and is applicable to the 2003 estimate because there has been no change in the data source since the ICF study was completed.

For the subsector of magnesium production, the methodology and data sources remain consistent over the time series. Emissions from two primary magnesium smelters, Norsk Hydro and Timminco, have been reported directly to Environment Canada since 1990. Estimates of SF_6 emissions from all three smelters, including Magnola, which started up in 2000, have been submitted to the NPRI since 1999.

According to the Cheminfo study (Cheminfo Services, 2005), the 2003 SF_6 emission estimate for magnesium casters has an uncertainty of 4%. This is a weighted average depending on each company's consumption of SF_6 and the overall data availability for 2003.

The data source remains consistent over the time series. The methodology, which is equating consumption of SF_6 as a cover gas by magnesium casters to emissions of SF_6, is applied over the time series with some assumptions, as discussed in the methodology section.

4.7.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

Magnesium Production is a key category that has undergone for this submission Tier 1 QC checks as elaborated in the *Framework for a Quality Assurance and Quality Control Plan* (SNC Lavallin, 2004). The checks performed are consistent with the Tier 1 General Inventory Level QC Procedures outlined in the IPCC Good Practice Guidance (IPCC, 2000). No issues of importance were detected from the Tier 1 QC process.

For magnesium casting, informal QC measures, such as double-checking calculations and checking activity data and emissions against the ones of previous years, have been taken.

4.7.5 CATEGORY-SPECIFIC RECALCULATIONS

There have been no recalculations of SF_6 emissions related to magnesium production.

In previous inventories, magnesium casters were considered as a potential source of SF_6 emissions, but no emission estimates were included. These emissions, which simply equal SF_6 consumption in casters, are now included in the inventory. Details on the estimation methodology are provided above.

4.7.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

There are currently no improvements planned specifically for estimating SF_6 emissions from magnesium production in Canada.

For the estimation of SF_6 emissions from magnesium casters, it is planned to utilize results of the completed questionnaires once they become available.

4.8 PRODUCTION AND CONSUMPTION OF HALOCARBONS (CRF CATEGORIES 2.E & 2.F)

4.8.1 SOURCE CATEGORY DESCRIPTION

Since HFCs were not widely used before the ban on production and use of CFCs came into effect in 1996 (as a result of the Montreal Protocol), emissions from HFC consumption were considered negligible for the period 1990–1994. CFCs are GHGs that are not included under the UNFCCC because they are already controlled under the Montreal Protocol. As a result, CFCs are not inventoried herein. Air conditioning (AC) equipment and refrigeration equipment represent the primary sources of HFC emissions. There is no known production of HFCs/PFCs in Canada.

Emissions from the consumption of PFCs are minor relative to the by-product emissions of PFCs from aluminium production. PFC emissions from aluminium production are discussed in Section 4.6 on Aluminium Metal Production. All HFCs/PFCs consumed in Canada are imported in bulk or in products (e.g., refrigerators).

4.8.2 METHODOLOGICAL ISSUES

HFC emission estimates for 1995 were based on data gathered from an initial HFC survey conducted by the Chemical Controls Division of Environment Canada in 1996. Environment Canada has revised subsequent surveys to obtain more detailed activity data. Surveys were conducted in 1998, 1999, and 2001 to collect data for the years 1996–2000. In some cases, one survey was done to collect data for two years. HFC activity data for 2001–2003 are currently unavailable. Data on the quantities of HFCs contained in imported and exported equipment were also not available for the years 1995, 1999, and 2000. For 1995, they were assumed to be zero. For 1999 and 2000, these quantities were assumed to stay at the 1998 level.

Detailed 1995 HFC data were not available to apply an IPCC Tier 2 estimate. Instead, a modified Tier 1 methodology was used to obtain a representative estimate of the actual 1995 HFC emissions for the following groups: Aerosols; Foams; Air Conditioning Original Equipment Manufacture (AC OEM); AC Service; Refrigeration; and Total Flooding System. To estimate 1996–2000 HFC emissions, an IPCC Tier 2 methodology was applied. Since consumption data for 2001–2003 are not available, emission estimates for these years are assumed to remain at the 2000 level.

The IPCC Tier 2 methodology was used to estimate emissions from consumption of PFCs for the years 1995–1997. The activity data were obtained through the 1998 PFC survey conducted by Environment Canada. As recent data are currently unavailable, emission estimates are assumed to be constant since 1997.

4.8.2.1 HFC Estimates for 1995: Emission Factors and Assumptions

HFC emission estimates for 1995 used an adapted IPCC Tier 1 method (IPCC/OECD/IEA, 1997). Emission factors for 1995 were developed based on loss rates adapted from the IPCC/OECD/IEA (1997) methodology.

AC Original Equipment Manufacture

Only original charging losses were estimated using the emission factors for this sector. Other losses were accounted for under AC Service. The IPCC guidelines (IPCC/OECD/IEA, 1997) suggest a 2–5% loss rate. For Canada, a rate of 4% was assumed.

AC Service

It was assumed that most AC-related use of HFCs was due to the replacement of operating losses. A loss rate of 100% was employed.

Refrigeration

It was assumed that all refrigeration in Canada falls under the IPCC other (i.e., commercial and industrial) category, since this was the dominant emission source. It was further assumed that refrigeration HFCs represented those used for initial and subsequent recharging of equipment. Therefore:

Equation 4-1:

HFC (refrig) = Charge + Operating Loss

The IPCC considers that operating loss is approximately 0.17(charge) (IPCC/OECD/IEA, 1997). Therefore, assuming the total charge remains constant for the short term:

HFC (refrig) = Charge + 0.17(Charge) = 1.17(Charge)

or

Charge = HFC (refrig)/1.17

Assuming assembly leakage was minimal:

Emission = Operating Loss = 0.17(Charge)

Thus,

Equation 4-2:

Emission = 0.17 {[HFC (refrig)]/1.17}

4.8.2.2 HFC/PFC Estimates for 1996–2000: Emission Factors and Assumptions

To estimate emissions of HFCs and PFCs during assembly, during system operation, and at disposal for 1996 onward, the IPCC Tier 2 methodology presented in the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) was applied.

System Assembly

To estimate emissions from system assembly, four types of equipment categories were considered: residential refrigeration, commercial refrigeration, stationary AC, and mobile AC. The equation below, found in the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997), was used to estimate emissions during system assembly for each type of equipment:

Equation 4-3:

$E_{assembly,\,t} = E_{charged,\,t} \cdot k$

where:

$E_{assembly,\,t}$ = emissions during system manufacture and assembly in year t

$E_{charged,\,t}$ = quantity of refrigerant charged into new systems in year t

k = assembly losses in percentage of the quantity charged

The k value was chosen from a range of values that were provided for each equipment category in the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) (see Table 4-4). The HFC and PFC survey provided quantity of refrigerant charged.

TABLE 4-4: Equipment Categories and k Values

Equipment Category	k Values (%)
Residential Refrigeration	2.0
Commercial Refrigeration	3.5
Stationary Air Conditioning	3.5
Mobile Air Conditioning	4.5

Annual Leakage

The same four categories from system assembly were considered in the calculations of emissions due to leakage. The equation below, given in the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997), was used to calculate HFC and PFC emissions from leakage:

Equation 4-4:

$E_{operation,\,t} = E_{stock,\,t} \times x$

where:

$E_{operation,\,t}$ = quantity of HFCs/PFCs emitted during system operations in year t

$E_{stock,\,t}$ = quantity of HFCs/PFCs stocked in existing systems in year t

x = annual leakage rate in percentage of total HFC/PFC charge in the stock

The amount of HFCs/PFCs stocked in existing systems includes the HFCs/PFCs in equipment manufactured in Canada, the amount of HFCs/PFCs in imported equipment, and the amount of HFCs in converted CFC equipment and excludes the amount of HFCs/PFCs in exported equipment. The amount of HFCs used in converted CFC equipment was estimated based on the amount of HFCs used for servicing equipment. It was assumed that no leakage occurred in the year of manufacturing or conversion. The IPCC guidelines (IPCC/OECD/IEA, 1997) give a range of values for the annual leakage rate (x) for each of the different equipment categories. The annual leakage rate chosen for each category is shown in Table 4-5 (IPCC/OECD/IEA, 1997).

TABLE 4-5: Annual Leakage Rate (x)

Equipment Category	x Values (%)
Residential Refrigeration	1.0
Commercial Refrigeration	17.0
Stationary Air Conditioning	17.0
Mobile Air Conditioning	15.0

System Disposal

HFC emissions from system disposal were not estimated, since HFC use began only in 1995, and emissions were assumed to be negligible.

PFC emissions from system disposal were not estimated due to a lack of data. Also, PFC emissions from systems that have been disposed of were assumed to be insignificant due to their limited use for specialized cooling systems prior to 1995.

Foam Blowing

HFC emission estimates for 1995 used an adaptation of the IPCC Tier 1 default method (IPCC/OECD/IEA, 1997). For that year, it was assumed that all foams produced were open cell foams. Emission factors for 1995 were developed based on loss rates adapted from the IPCC methodology (IPCC/OECD/IEA, 1997).

The IPCC Tier 2 methodology presented in the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) was used to estimate HFC and PFC emissions from foam blowing from 1996 onward. Foams are grouped into two main categories: open cell and closed cell.

■ Open Cell Foam Blowing

In the production of open cell foam, 100% of the HFCs used are emitted (IPCC/OECD/IEA, 1997). At present, there is no known PFC use in open cell foam blowing. Environment Canada's HFC survey provided consumption data on the following open cell foam production categories that release HFC emissions:

- Cushioning — Automobiles;
- Cushioning — Others;
- Packaging — Food;
- Packaging — Others; and
- Other Foam Uses.

■ Closed Cell Foam Blowing

During the production of closed cell foam, approximately 10% of the HFCs/PFCs used are emitted (IPCC/OECD/IEA, 1997). The remaining quantity of HFCs/PFCs is trapped in the foam and is emitted slowly over a period of approximately 20 years. The IPCC Tier 2 equation (as shown below) was used to calculate emissions from closed cell foam:

Equation 4-5:

$$E_{\text{foam, t}} = 10\%\ E_{\text{manufacturing, t}} + 4.5\%\ E_{\text{foam stock, t}}$$

where:

$E_{\text{foam, t}}$ = emissions from closed cell foam in year t

$E_{\text{manufacturing, t}}$ = quantity of HFCs/PFCs used in manufacturing closed cell foam in year t

$E_{\text{foam stock, t}}$ = quantity of HFCs/PFCs in stock (excluding exports) in year t

Quantities of HFCs/PFCs used in manufacturing and in stock of closed cell foam were provided by Environment Canada's HFC/PFC survey. The following are closed cell foam production categories that produce HFC emissions:

- Thermal Insulation — Home and Building;
- Thermal Insulation — Pipe;
- Thermal Insulation — Refrigerator and Freezer; and
- Thermal Insulation — Other.

Fire Extinguishers

HFC emission estimates for 1995 used an adaptation of the IPCC Tier 1 default method (IPCC/OECD/IEA, 1997). Emission factors for 1995 were developed based on loss rates adapted from the IPCC methodology (IPCC/OECD/IEA, 1997).

There are two types of fire-extinguishing equipment considered: portable fire extinguishers and total flooding systems. The IPCC Tier 2 methodology of the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) was used to calculate HFC emissions from portable fire extinguishers and total flooding systems from 1996 onward. At present, there is no known PFC use in fire-extinguishing equipment.

- **Portable Fire-Extinguishing Equipment**

The IPCC Tier 2 methodology in the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) estimated emissions as 60% of HFCs used in newly installed equipment. The quantity of each type of HFCs was provided by Environment Canada's HFC survey.

- **Total Flooding Systems**

The IPCC Tier 2 methodology provided in the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) estimated emissions from total flooding systems as 35% of the HFCs used in new fire-extinguishing systems installed. The amount of each type of HFC used in new systems was provided by Environment Canada's HFC survey.

Aerosols/Metered Dose Inhalers

HFC emission estimates for 1995 used an adaptation of the IPCC Tier 1 default method (IPCC/OECD/IEA, 1997). Emission factors for 1995 were developed based on loss rates adapted from the IPCC methodology (IPCC/OECD/IEA, 1997).

The IPCC Tier 2 methodology presented in the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) was used to calculate HFC emissions from aerosols from 1996 onward. The emission estimate for the current year is equal to half of the HFCs used in aerosols in the current year plus half of the HFCs used in aerosols in the previous year. The amount of HFCs used each year is equal to the amount of HFCs used to produce aerosols and the amount of HFCs in imported aerosol products and excludes the amount of HFCs in exported aerosol products. The amounts of each type of HFC used in manufactured, imported, and exported aerosol products were provided by Environment Canada's HFC survey.

Solvents

The IPCC Tier 2 methodology presented in the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) was used to estimate HFC and PFC emissions from solvents from 1996 onward. The emission estimate for the current year is equal to half of the HFCs/PFCs used as solvents in the current year plus half of the HFCs/PFCs used as solvents in the previous year. The amount of HFCs/PFCs used each year is equal to the amount of HFCs/PFCs produced and imported as solvents and excludes the amount of HFCs/PFCs exported as solvents. The activity data were provided by Environment Canada's HFC survey. HFCs/PFCs used as solvents include the following categories:

- electronics industries;
- laboratory solvents; and
- general cleaning.

Semiconductor Manufacture

There are two main uses of PFCs in the semiconductor manufacturing industry: plasma etching of silicon wafers and plasma cleaning of chemical vapour deposition chambers.

IPCC Tier 2b methodology was used to estimate PFC emissions from the semiconductor manufacturing industry.

Bulk PFC consumption data were obtained from Environment Canada's PFC survey. To estimate emissions, the consumption data are multiplied by the Tier 2b emission rates shown in Table 4-6. As no information on emission control technologies for these processes is currently available, no emission control factor is applied (IPCC, 2000).

TABLE 4-6: PFC Emission Rates[1]

	Emission Rate			
Process	**CF_4**	**C_2F_6**	**C_3F_8**	**$c\text{-}C_4F_8$**
Plasma Etching	0.7	0.4	0.4	0.3
Chemical Vapour Deposition Chamber	0.8	0.7	0.4	N/A

Notes:

[1] Tier 2b, from IPCC (2000).

N/A = no data available

Other Sources

Minor amounts of PFC emissions have been identified as related to its use in the electronics industry for emissive applications, including reliability testing (inert liquids), coolants (direct evaporative cooling for electric and electronic apparatuses and indirect coolants in closed circuit electronic apparatuses), and precision cleaning (IPCC, 2000). More specifically, these emissions can come from two types of sources: emissive and contained.

Emissive sources include the following:

- electrical environmental testing;
- gross leak testing; and
- thermal shock testing.

Unidentified and miscellaneous PFC uses reported in the PFC survey were also considered as part of emissive sources. According to the IPCC Tier 2 methodology, 50% of PFCs used for the above purposes would be released during the first year and the remaining 50% released in the following year.

Contained sources consist of PFC use as an electronic insulator and a dielectric coolant for heat transfer in the electronics industry. The IPCC Tier 2 emission factors (IPCC, 2000) are applied to the PFC use data obtained from the PFC survey to estimate PFC emissions from contained sources, as follows:

Equation 4-6:

$$E_{contained,\,t} = (k \times E_{consumed,\,t}) + (x \times E_{stock,\,t}) + (d \times E_{consumed,\,t})$$

where:

$E_{contained,\,t}$ = emissions from contained sources

$E_{consumed,\,t}$ = quantity of PFC sale for use or manufacturing of contained sources in year t

$E_{stock,\,t}$ = quantity of PFCs in stock in year t

k = manufacturing emission rate = 1% of annual sales

x = leakage rate = 2% of stock

d = disposal emission factor = 5% of annual sales

4.8.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

It is stated in the ICF report (ICF, 2004) that since the uncertainty models for consumption of halocarbons as well as the uncertainty assessment of input data were done with several assumptions, the uncertainty estimates developed for this subsector should be considered preliminary.

The uncertainty in the 2001 HFC emission estimate, provided in the ICF (2004) report, was estimated to be within the range of -21% to 55%. By and large, the uncertainty range corresponds to a highly conservative estimate for the total 2003 HFC emissions. Improvements made for estimating "E_{stock}" (in Equations 4-4 and 4-5) and acquisition of more recent consumption data are believed to have brought down the uncertainty around the HFC emission estimate. To assess the quantitative impact that these changes have on the uncertainty range, an updated detailed analysis needs to be conducted. Possible sources of uncertainty for this category are (i) the IPCC default emission rates, which may not be totally applicable to a Canadian context, and (ii) data on HFC quantities found in imported/exported products.

An uncertainty range of -28% to 70% was reported in the ICF study (ICF, 2004) for the 2001 PFC emission estimate. This is applicable to the 2003 inventory year estimates because there has been no change in the methodology and data source used since the ICF study was completed. Uncertainty for this category is mainly due to the assumption that emissions for the years after 1997 stay constant at the 1997 level (also see Planned Improvements).

For both HFC and PFC emissions of this subsector, the IPCC default emission rates have been consistently applied over the time series. The data source for the time series has been surveys conducted by the Chemical Controls Division of Environment Canada.

4.8.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

Consumption of halocarbons resulting in HFC emissions is a key category that has undergone for this submission Tier 1 QC checks as elaborated in the *Framework for a Quality Assurance and Quality Control Plan* (SNC Lavallin, 2004). The checks performed are consistent with the Tier 1 General Inventory Level QC Procedures outlined in the IPCC Good Practice Guidance (IPCC, 2000).

Informal QC measures have been taken for PFC emission estimates under this subsector.

4.8.5 CATEGORY-SPECIFIC RECALCULATIONS

The estimated value of the parameter "E_{stock}" (shown in Equations 4-4 and 4-5) has been revised for the period 1996–1998. This change has resulted in a significant increase in HFC emissions of approximately 65–100% for the same period. Because of the acquisition of some newer HFC consumption data — namely, those for the years 1999 and 2000 — the emissions from use of HFCs for the years 1999–2000 have also been recalculated. The HFC emissions for these two years were previously assumed to remain at the 1998 level due to lack of data.

4.8.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

Future improvement plans will focus on a thorough review of the methodology used for estimating HFC emissions based on survey data. Efforts will also focus on acquiring more recent data on consumption of PFCs and HFCs and reviewing the previously obtained import and export data.

4.9 PRODUCTION AND CONSUMPTION OF SF_6 (CRF CATEGORIES 2.E & 2.F)

4.9.1 SOURCE CATEGORY DESCRIPTION

There is currently no production of SF_6 in Canada; therefore, all Canadian supply of SF_6 is obtained through imports. From 1990 to 1996, SF_6 imports from the United States comprised more than 95% of total imports; however, in recent years, this percentage has declined, with an increase in SF_6 imports from Germany (Cheminfo Services, 2002).

In addition to magnesium production and casting, electrical equipment in utilities is one of the known sources of SF_6 emissions. SF_6 is used as an insulating and arc-quenching medium in high-tension electrical equipment, such as electrical switchgear, stand-alone circuit breakers, and gas-insulated substations.

4.9.2 METHODOLOGICAL ISSUES

The method used for estimating SF_6 emissions from electrical equipment in utilities was a top-down approach, assuming that all SF_6 purchased from gas distributors replaces SF_6 lost through leakage.

In a study conducted by Cheminfo Services (2002) to review and assess potential SF_6 emission sources in Canada, several Canadian utilities reported that new equipment is typically delivered with a few cylinders of SF_6 supplied for charging by the original equipment manufacturer (OEM). This implies that the amount of SF_6 purchased from OEMs can be small compared with the quantity bought from gas distributors. Hence, it is assumed that 100% of the SF_6 sales from gas distributors to utilities are used to refill leaking equipment and that SF_6 supplied by OEMs is added to new stock and not emitted.

This method would be considered a modified Tier 1 method because it follows the Tier 1 logic in assuming that all of the SF_6 purchased from gas distributors goes to replace SF_6 lost through leakage. However, it would be considered as "modified" because it focuses only on gas distributor SF_6 sales (Cheminfo Services, 2005).

Gas distributors have been requested to submit their annual SF_6 sales data by market segment, so this modified Tier 1 method can be applied. However, due to time constraints, only sales data for 1995–2000 inclusively have been collected so far. Alternative approaches were applied to estimate SF_6 sales for the other years of the time series. For example, a backcast from 1995 data on global SF_6 sales to the utilities market segment has been done to estimate 1990–1994 sales. The 2001–2003 sales estimates were based on data on imports obtained from Statistics Canada and the use of SF_6 in other sectors (Cheminfo Services, 2005).

4.9.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

According to the recent study conducted by Cheminfo Services (2005), the uncertainty range for the emission estimate of 2003 is -50% to +19%. For most years of the whole time series, the uncertainty range shows a downward bias, which reflects the belief that SF_6 emissions are more likely to be overestimated than underestimated (Cheminfo Services, 2005). The uncertainty can generally be explained by the drawbacks that the current methodology may have. For example, not all SF_6 purchased from a gas distributor is used in its entirety, and oversupplied SF_6 cylinders could be returned to the distributors (Cheminfo Services, 2005); however, the methodology assumes that SF_6 emissions in a year are equal to the SF_6 sales in that year. Nevertheless, it is recognized that given the current lack of electricity release data, this approach would be the simplest method for estimating SF_6 emissions until SF_6 emission data reported by utilities, through the Canadian Electricity Association's (CEA) Environmental Commitment and Responsibilities (ECR) program, become available to the GHG Division.

The data source and methodology used are consistent over the time series.

4.9.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

Informal QC has been performed for SF_6 emissions from electrical equipment. For example, to verify whether the average emission fraction of 100% is reasonable, an expert who helps prepare the U.S. EPA's High GWP Gas Inventory has been contacted during the course of a recent study that is to be completed (Cheminfo Services, 2005). According to this expert, the SF_6 gas supplied by gas distributors to utilities is almost entirely used for leak replacement. This view supports the use of the modified Tier 1 method. It is also indicated in the same study that the CEA SF_6 Task Group generally supports the proposed method as an interim methodology to be used until SF_6 data from utilities can be gathered. Moreover, this group has acknowledged that there are no better data at present to improve the methodology.

4.9.5 CATEGORY-SPECIFIC RECALCULATIONS

In previous inventories, electrical equipment in utilities has been recognized as a potential source of SF_6 emissions. Estimates of these emissions are now included in the inventory. Details on the estimation methodology are described above.

4.9.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

The CEA has indicated in the study mentioned above (Cheminfo Services, 2005) that most major utilities plan to submit SF_6 emission estimates for 2004 calculated by the mass balance method (Tier 3b) by mid-2005 as part of their obligations under the CEA's ECR Program. The possibility of getting these data from the CEA once they become available will be examined.

4.10 OTHER AND UNDIFFERENTIATED PRODUCTION (CRF CATEGORY 2.G)

4.10.1 SOURCE CATEGORY DESCRIPTION

Emissions from this subsector are from the non-energy use of fossil fuels and are not accounted for under any of the other subsectors of Industrial Processes. Examples of fuels in non-energy applications are the use of natural gas to produce hydrogen in the oil sands upgrading and refining industries, the use of petroleum coke for anodes in metal production, the use of NGLs and feedstocks in the chemicals industry, and the use of lubricants. All of them result in varying degrees of oxidation of the fuel, producing CO_2 emissions.

The use of fossil fuels as feedstocks or for other non-energy uses is reported in an aggregated manner by Statistics Canada (in publication #57-003) under "Non-Energy Use" for each individual fuel. In the event that CO_2 emissions resulting from non-energy fuel use are allocated to another category of the Industrial Processes Sector (as is the case for ammonia production and aluminium production), those emissions are subtracted from the total non-energy emissions to avoid double-counting.

4.10.2 METHODOLOGICAL ISSUES

General emission rates for non-energy use of fuels, expressed as grams of CO_2 emitted per unit of fossil fuel used as feedstock or non-energy product, were developed based on the total potential CO_2 emission rates and the IPCC default percentages of carbon stored in products. The potential CO_2 emission rates were derived from the carbon emission factors shown in the McCann study (McCann, 2000).

Fuel quantity data for non-energy fuel usage were reported by the RESD (Statistics Canada, #57-003). It should be noted that the RESD data for any given year are preliminary and subject to revisions in subsequent publications. These data were multiplied by the emission rates mentioned above (also shown in Annex 13) to estimate CO_2 emissions for this subsector.

This technique is considered to be a Tier 1-type method, as it is based on the use of national consumption data and average national emission factors. Methodological issues for calculating CO_2 emissions from the non-energy use of fossil fuels are not addressed specifically in the IPCC Good Practice Guidance (IPCC, 2000).

For certain cases, industry- and process-specific data were available. For example, the use of natural gas to produce hydrogen in oil refining and oil sands upgrading is reported as natural gas transformed to refined products and natural gas inter-product transfer by the RESD (Statistics Canada, #57-003), respectively. In these instances, relevant emission factors were applied.

4.10.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

An uncertainty range of -40% to 1% reported in the ICF (2004) study for estimates of CO_2 emissions from non-energy use of fuels is generally applicable to the 2003 estimate because there has been no change in the methodology and data source used since the ICF study was completed. The uncertainty range implies that emissions from this category are likely to be overestimated. It also seems to reflect the predominant influence of the uncertainty associated with (i) the emission factor for petroleum coke and (ii) the CO_2 emissions from ammonia production (ICF, 2004).

The data sources and methodology used are consistent over the time series.

4.10.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

Other and Undifferentiated Production is a key category that has undergone for this submission Tier 1 QC checks as elaborated in the *Framework for a Quality Assurance and Quality Control Plan* (SNC Lavallin, 2004). The checks performed are consistent with the Tier 1 General Inventory Level QC Procedures outlined in the IPCC Good Practice Guidance (IPCS, 2000).

4.10.5 CATEGORY-SPECIFIC RECALCULATIONS

The 2002 emissions have been recalculated due to acquisition of updated 2002 data on non-energy fuel use.

4.10.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

There are currently plans to apply a Tier 2-type methodology to estimate emissions arising from non-energy-related use of hydrocarbons in future inventories. This may become possible with the use of industrial consumption of energy data obtained from Statistics Canada and application-specific emission factors from a research study under way.

5 SOLVENT AND OTHER PRODUCT USE (CRF SECTOR 3)

One distinction between the sources in the Solvent and Other Product Use Sector and those in the Industrial Processes Sector is that the former are generally area sources.

The majority of emissions in this sector are related to the use of N_2O as an anaesthetic and propellant. Emissions from paint application, degreasing, dry cleaning, and chemical products manufacture and processing are not estimated.

5.1 N_2O FROM ANAESTHETICS AND PROPELLANTS

5.1.1 SOURCE CATEGORY DESCRIPTION

N_2O is used in medical applications, primarily as a carrier gas but also as an anaesthetic in various dental and veterinary applications. It has been assumed that all of the N_2O used for anaesthetics will eventually be released to the atmosphere.

N_2O is also used as a propellant for pressure and aerosol products, primarily in the food industry. The largest application is for pressure-packaged whipped cream as well as other dairy products. Applications outside of the food industry include the cosmetic industry and the use as a substitute for Freon or hydrocarbons, such as butane and isobutane.

5.1.2 METHODOLOGICAL ISSUES

Based on the 1990 population statistics and the N_2O consumption patterns in medical applications (W. Fettes, personal communication, 1994), an emission factor of 46.2 g N_2O per capita was developed for estimating N_2O emissions from its use as an anaesthetic. This factor is slightly lower than the one developed for the United States.

For N_2O used as a propellant, an emission factor of 2.38 g N_2O per capita was derived based on consumption patterns in Canada in 1990. It was assumed that all the N_2O used in propellants was emitted to the atmosphere during the year of sale.

The annual population statistics from Statistics Canada's publication #91-213 were multiplied by each of the emission factors to estimate N_2O emissions for this sector.

5.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty associated with the 2001 emission estimate of this sector was estimated to be within the range of -23% and 22% (ICF, 2004). As the methodology and data source have not changed since the completion of the ICF study, this is applicable to the 2003 inventory estimate. It can primarily be attributed to the uncertainty around the emission factors.

The data source and methodology used are consistent over the time series.

5.1.4 QA/QC AND VERIFICATION

Informal QC checks, such as double-checking calculations and checking population data and emission estimates against the ones of previous years, have been done.

5.1.5 RECALCULATIONS

Recalculations were conducted for 1990–2003 based on revised demographic statistics provided by Statistics Canada.

5.1.6 PLANNED IMPROVEMENTS

As the uncertainty around the emission factors seems to have caused uncertainty in the emission estimates, the possibility of updating the emission factors will be investigated.

6 AGRICULTURE (CRF SECTOR 4)

Emission sources from agriculture include CH_4 and N_2O emissions from animal production — namely, from enteric fermentation and manure management — and N_2O released from agricultural soils. Due to changes to the international reporting guidelines, emissions or removals of CO_2 from agricultural soils, which were previously reported under the Agriculture Sector, are now reported under the LULUCF Sector under the "Cropland Remaining Cropland" category (see Chapter 7). This has a significant impact on the trend of GHG emissions from the Agriculture Sector (see Overview below). It also has an effect on the national trend, given that GHGs from the LULUCF Sector are excluded from national totals.

In addition, a number of changes were introduced this year in the inventory for this sector to take into account method and data improvements. First, inventory methodologies for enteric fermentation of cattle and CH_4 emissions from manure management practices have been upgraded from IPCC Tier 1- to IPCC Tier 2-type, as is required for key categories. Secondly, a few new animal categories have been included. Emissions from buffaloes are now accounted for, and goats and horses have been added to the manure CH_4 category. Some animal population accounts — namely, goats and poultry (chicken and turkey) — were revised and/or updated, leading to recalculations. Other changes pertain to the further implementation of IPCC Good Practice Guidance (IPCC, 2000). Details can be found in the Recalculations subsection of each source category below.

Some minor GHG sources are not included. CH_4 emissions from rice production in Canada are considered to be negligible and are not inventoried. Similarly, field burning of agricultural residues is no longer considered a common practice in Canadian agriculture and therefore is not inventoried. Prescribed burning of savannas is not a relevant practice in Canada. GHG emissions from on-farm fuel combustion are included in the Energy Sector (Chapter 3).

For each emission source category, a brief introduction and a description of methodological issues, uncertainties and time-series consistency, QA/QC and verification, recalculations, and planned improvements are provided. The detailed inventory methodologies and sources of activity data are described in Section A3.1 of Annex 3.

Total GHG emissions from the Canadian Agriculture Sector were 52 Mt in 1990, 59 Mt in 2002, and 62 Mt in 2003 (Table 6-1). This represents an increase of approximately 19% between 1990 and 2003, mainly resulting from the expansion in the beef cattle, swine, and poultry industry as well as an increase in synthetic nitrogen fertilizer consumption. In addition, the change in the reporting category of CO_2 emissions and removals from agricultural soils to the LULUCF Sector significantly affected the total agricultural emissions as well as the relative change from 1990. The increase in GHGs for the sector over 1990–2002 is now 13.8% compared with the 1% change previously reported when CO_2 emissions and removals from agricultural soils were included.

There was a significant increase in emissions of N_2O from agricultural soils of 2.6 Mt between 2002 and 2003. This increase is mainly due to a higher crop production in 2003 over the previous year. The year 2002 has seen a severe drought in most regions of Canada.

TABLE 6-1: Short- and Long-Term Changes in GHG Emissions from the Agriculture Sector

kt CO_2 eq

GHG Source Category		1990	2002	2003
Agriculture TOTAL		**52 000**	**59 000**	**62 000**
Enteric Fermentation — CH_4	Dairy Cattle	3 630	2 850	2 810
	Beef Cattle	14 400	18 400	18 600
	Others	640	1 010	1 010
Manure Management — CH_4	Dairy Cattle	940	740	720
	Beef Cattle	720	820	830
	Swine	1 400	2 000	2 000
	Poultry	90	120	120
	Others	20	30	30
Manure Management — N_2O	All Animal Types	3 500	4 100	4 100
Agricultural Soils — Direct N_2O	Synthetic Nitrogen Fertilizers	6 600	8 600	8 800
	Manure Applied as Fertilizers	2 800	3 300	3 300
	Leguminous Crops	3 800	3 200	3 800
	Crop Residue Decomposition	6 000	4 500	6 200
	Manure on Pasture	2 600	3 300	3 300
	Cultivation of Organic Soils	60	60	60
Agricultural Soils — Indirect N_2O		5 000	6 000	7 000

6.1 ENTERIC FERMENTATION (CRF CATEGORY 4.A)

6.1.1 SOURCE CATEGORY DESCRIPTION

Large quantities of CH_4 are produced from herbivores through a process called enteric fermentation. During the normal digestive process, microorganisms break down carbohydrates into simple molecules for absorption into the bloodstream, where CH_4 is produced as a by-product. This process results in CH_4 in the rumen, which is emitted by eructation and exhalation. Some CH_4 is released later in the digestive process by flatulation. Ruminant animals, such as cattle, generate the most CH_4.

6.1.2 METHODOLOGICAL ISSUES

CH_4 emissions from enteric fermentation of cattle are estimated using the IPCC Tier 2 methodology. Emission factors for various cattle categories were determined following the guidelines provided by IPCC (2000) and based on a recent study by Boadi et al. (2004). To achieve this, it was necessary to characterize the cattle population according to animal type, physiological status, age, gender, weight, rate of gain, level of activity, and production environment. Much of this information was not available in the published literature and required contact with beef and dairy cattle specialists across the country. This information was used to calculate emission factors associated with various cattle categories based on the IPCC Tier 2 equations and in conjunction with Statistics Canada population data to generate estimates of enteric emissions for each province.

For non-cattle animal populations, CH_4 emissions from enteric fermentation continue to be estimated using IPCC Tier 1 methodology. Poultry are excluded from enteric fermentation estimates, since no emission factors are available from the IPCC guidelines (IPCC/OECD/IEA, 1997) or the literature. CH_4 emissions are calculated for each animal category, multiplying the animal population by the emission factor associated with the specific animal category.

Domestic animal population data are obtained from the Census of Agriculture and other Statistics Canada reports listed in Table 6-2. Semi-annual or quarterly data are averaged to obtain annual populations.

6.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties associated with animal populations are generally low, ranging from 0% for swine, ±1% for cattle, and ±2% for sheep and lambs to ±15% for horses and goats. Uncertainties associated with the IPCC default emission factors (IPCC/OECD/IEA, 1997) are estimated to be ±20%. The overall uncertainty for emission estimates based on the IPCC Tier 1 methodology is estimated to be ±9% (ICF, 2004). Since the IPCC Tier 2 methodology for cattle is applied, the uncertainty associated with the enteric fermentation emission estimate is expected to be lower, but the quantitative assessment of uncertainty based on the new methodology has not been done at this time.

The same methodology and emission factors are used for the entire time series of emission estimates (1990–2003).

TABLE 6-2: Animal Categories and Sources of Population Data

Category	Sources/Notes
Cattle	
Dairy Cattle	Dairy cows
Non-Dairy Cattle	All other cattle Data source: Statistics Canada (2003c)
Buffalo	Data are not available from Statistics Canada (2003c). Thus, data from the 1996 and 2001 farm census (Statistics Canada, 1997, 2002) have been used to derive the 1990–2003 time series
Sheep and Lambs	Data source: Statistics Canada (2003c)
Goats	Data are not available on an annual basis from Statistics Canada (2003c). Therefore, data from the 1991, 1996, and 2001 farm census (Statistics Canada, 1992, 1997, 2002) have been used.
Camels and Llamas	Considered a negligible source in Canada
Horses	Data are not available from Statistics Canada (2003c). Therefore, data from the 1991, 1996, and 2001 farm census (Statistics Canada, 1992, 1997, 2002) have been used.
Mules and Asses	Considered a negligible source in Canada
Swine	All pigs Data source: Statistics Canada (2003c)
Poultry	Yearly population data of laying hens are available from *Production of Poultry and Eggs* (Statistics Canada, 2003b). Chicken and turkey population data are available from the 1991, 1996, and 2001 farm census (Statistics Canada, 1992, 1997, 2002).

6.1.4 QA/QC AND VERIFICATION

Enteric fermentation, as a key category, has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2002). In addition, the activity data, methodologies, and changes are documented and archived in both paper and electronic form. The IPCC Tier 2 emission factors for cattle derived from Boadi et al. (2004) have been reviewed by independent experts.

Direct measurements of CH_4 emissions from enteric fermentation in Canada are recent, and data are still scarce. Over the last few years, a number of Canadian researchers have adopted a tracer technique for measuring CH_4 emissions from grazing cattle using SF_6 (McCaughey et al., 1997, 1999; Boadi and Wittenberg, 2002; Boadi et al., 2002a, 2002b). CH_4 measurements in the scientific literature are currently being compiled by the GHG Division for purposes of future comparison and verification.

6.1.5 RECALCULATIONS

Recalculations have been carried out because of changes in emission factors for cattle with the adoption of the new Tier 2 methodology, the addition of new animal categories (buffaloes), as well as revising the goat population from 1990 to 1995. Overall, these recalculations increased the reported 1990 emissions by about 2.7 Mt and the 2002 emissions by 3.4 Mt, compared with the 2004 submission, but have had a minimal impact on the long-term trend.

The implementation of the Tier 2 methodology for cattle resulted in an upward revision of CH_4 emissions from this source by 2.6 Mt in 1990 and 3.2 Mt in 2002. The addition of buffaloes increased emissions by 0.05 Mt in 1990 and 0.17 Mt in 2002. Revising the goat population from 1990 to 1995 also increased emissions by 0.1 Mt annually for those years.

6.1.6 PLANNED IMPROVEMENTS

Quantitative assessment of uncertainty associated with this source of emissions based on the IPCC Tier 2 methodology is planned. It is expected that this will be implemented in time for the 2006 submission. In addition, potential changes in emission factors for dairy cattle over time will be investigated to reflect changes in milk production.

6.2 MANURE MANAGEMENT (CRF CATEGORY 4.B)

During the handling or storage of livestock manure, both CH_4 and N_2O are emitted. The magnitude of the emissions depends upon the quantity of manure handled, the manure properties, and the type of manure management system. Typically, poorly aerated manure management systems generate large quantities of CH_4 but smaller amounts of N_2O, while well-aerated systems generate little CH_4 but more N_2O.

6.2.1 METHANE EMISSIONS FROM MANURE MANAGEMENT (CRF CATEGORY 4.B(a))

6.2.1.1 Source Category Description

Shortly after manure is excreted, it begins to decompose. If little oxygen is present, the decomposition will be mainly anaerobic and thus produces CH_4. The quantity of CH_4 produced depends on the type of waste management system — in particular, the amount of aeration — and the quantity of manure.

6.2.1.2 Methodological Issues

CH_4 emissions from manure management are estimated using the IPCC Tier 2 methodology. Emission factors for each animal category are derived following the guidelines provided by IPCC Good Practice Guidance (IPCC, 2000) and based on a recent study (Marinier et al., 2004). Emissions are calculated for each animal category, multiplying the animal population by the average emission factor associated with the specific animal category. The animal population data are the same as those used for the Enteric Fermentation emission estimates. Details are provided in Section A3.1 of Annex 3.

6.2.1.3 Uncertainties and Time-Series Consistency

Uncertainties associated with CH_4 emission estimates from manure management result from uncertainties associated with estimates of animal populations from the Census of Agriculture and uncertainties associated with emission factors. Uncertainties associated with animal populations are generally low, ranging from 0% for swine and poultry, ±1% for cattle, and ±2% for sheep and lambs to ±15% for horses and goats. Uncertainties associated with emission factors derived from the IPCC Tier 1 methodology are assumed to be ±25%. The overall uncertainty associated with this source of emissions using Monte Carlo simulations is ±15% (ICF, 2004). Since the IPCC Tier 2 methodology is applied, the uncertainty associated with the manure CH_4 emission estimate needs to be reassessed.

The same methodology and emission factors are used for the entire time series (1990–2003).

6.2.1.4 QA/QC and Verification

CH_4 from manure management has been subject to a change in method. Therefore, it has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2000). The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. The IPCC Tier 2 CH_4 emission factors from manure management practices by various animal types derived from Marinier et al. (2004) have been reviewed by independent experts.

6.2.1.5 Recalculations

Recalculations have been carried out for the entire time series because of changes in emission factors due to the adoption of a Tier 2 method, the addition of buffaloes, goats, and horses, and the revision to the poultry population accounts, as previously mentioned. Overall, these recalculations decreased the reported 1990 emissions by about 1. 5 Mt and the 2002 emissions by 2.0 Mt, compared with the 2004 submission, but have had a minimal impact on the long-term trend. Note that the change in animal waste management system (AWMS) distribution is already taken into account in the new Tier 2 emission factors derived in Marinier et al. (2004).

6.2.1.6 Planned Improvements

Quantitative assessment of uncertainty associated with this source of emissions based on the IPCC Tier 2 methodology is planned. It is expected that this will be implemented in time for the 2006 submission.

Direct measurements of CH_4 emissions from manure management in Canada are recent, and data are still scarce. Recent scientific advances in analytical techniques allow direct measurements of CH_4 emissions from point sources, such as lagoons, using a flux tower. However, it will take several years before we can reliably measure and verify CH_4 emissions from various manure management systems in Canada.

6.2.2 NITROUS OXIDE EMISSIONS FROM MANURE MANAGEMENT (CRF CATEGORY 4.B(b))

6.2.2.1 Source Category Description

The production of N_2O during storage and treatment of animal waste occurs during nitrification and denitrification of nitrogen contained in the manure. Nitrification is the oxidation of ammonium (NH_4^+) to nitrate (NO_3^-), and denitrification is the reduction of NO_3^- to N_2O or nitrogen (N_2). Generally, as the degree of aeration of the waste increases, so does the amount of N_2O produced.

In Canada, four major types of manure management systems or AWMS are typically used: liquid systems, solid storage and drylot, pasture and paddock and other systems. It is assumed that no manure is burned as fuel. Table 6-3 presents Canada's breakdown of manure nitrogen by AWMS. The distribution of manure management systems by animal category is based on a recent study by Marinier et al. (2004). Note that the N_2O emissions from manure in pasture and paddock systems are not included here but count as a direct N_2O source from agricultural soils (see Section 6.3.1.6).

TABLE 6-3: Percentage of Manure Nitrogen Handled by Animal Waste Management Systems

Animal Type	Liquid Systems	Solid Storage and Drylot	Pasture and Paddock	Other Systems
Non-Dairy Cattle	1	47	48	4
Dairy Cattle	42	40	18	0
Poultry	10	88	2	0
Sheep & Lambs	0	38	62	0
Swine	96	3	0	1
Other (Goats, Horses, and Buffaloes)	0	42	58	0

Source: Marinier et al. (2004).

6.2.2.2 Methodological Issues

N_2O emissions from manure management are estimated using the IPCC Tier 1 methodology. Emissions are calculated for each animal category by multiplying the animal population by the average nitrogen excretion rate associated with the specific animal category and by the fraction of available nitrogen based on the type of waste management system.

The animal population data are the same as those used for the Enteric Fermentation estimates (Section 6.1.2). The average annual nitrogen excretion rates for domestic animals are taken from research conducted in the United States (ASAE, 1999), which is believed to be more representative of the Canadian situation than the IPCC defaults. These excretion rates are reduced by 20% to account for the volatilization of NH_3 and NO_x (IPCC/OECD/IEA, 1997).

The fraction of nitrogen available for conversion into N_2O is estimated by applying system-specific emission factors to the manure nitrogen handled by each management system. The IPCC default emission factors (IPCC/OECD/IEA, 1997) for a developed country with a cool climate are used to estimate manure nitrogen emitted as N_2O for each type of AWMS. This factor is multiplied by the breakdown of AWMS by animal category (shown in Table 6-3) to derive the fraction of nitrogen that is converted into N_2O.

6.2.2.3 Uncertainties and Time-Series Consistency

Uncertainties associated with N_2O emission estimates from manure management result from uncertainties associated with estimates of animal populations (0–15%) from the Census of Agriculture, rates of nitrogen excretion (±30%), types of AWMS (±20%), and the emission factors associated with AWMS (±30%). The overall uncertainty associated with this source of emission estimates varies from -30% to +35% (ICF, 2004).

The same methodology and emission factors are used for the entire time series (1990–2003).

6.2.2.4 QA/QC and Verification

This category has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2000). The activity data, methodology, and changes to methodologies are documented and archived in both paper and electronic form.

6.2.2.5 Recalculations

Recalculations have been carried out because of the addition of buffaloes, the revision of the goat population from 1990 to 1995, the revision of poultry population data, as well as the change in percentage of manure nitrogen handled by AWMS. Overall, these recalculations decreased the reported 1990 emissions by 0.23 Mt and the 2002 emissions by 0.50 Mt, compared with the 2004 submission, but have had a minimal impact on the long-term trend.

There have been some updates in the distribution of AWMS types for major domestic animal categories (Marinier et al., 2004). For instance, manure on pasture and paddock increased, while solid storage and drylot managed manure decreased for non-dairy cattle, compared with those previously reported and used.

6.2.2.6 Planned Improvements

Direct measurements of N_2O emissions from manure management in Canada have only recently been initiated, and data are still scarce. Recent scientific advances on analytical techniques allow direct measurements of N_2O emissions from point sources, such as lagoons, using a flux tower. However, it will likely take several years before N_2O emissions can be reliably measured and verified from various manure management systems in Canada.

6.3 NITROUS OXIDE EMISSIONS FROM AGRICULTURAL SOILS (CRF CATEGORY 4.D)

Emissions of N_2O from agricultural soils consist of direct and indirect sources. Direct source emissions are, as their name implies, directly emitted from agricultural soils. These emissions result from nitrogen that has entered the soil from synthetic fertilizers, animal manure applied as fertilizer, manure on pasture and paddock from grazing animals, biological nitrogen fixation, crop residue decomposition, and the cultivation of histosols. Emissions from indirect sources are emitted off site through volatilization and leaching of synthetic fertilizer and manure nitrogen.

6.3.1 DIRECT NITROUS OXIDE EMISSIONS FROM SOILS (CRF CATEGORY 4.D.1)

6.3.1.1 Synthetic Nitrogen Fertilizers

Source Category Description

Synthetic fertilizers add large quantities of nitrogen to agricultural soils. This added nitrogen undergoes transformations (i.e., nitrification and denitrification) and releases N_2O. Emission rates associated with fertilizer application will depend on many factors, such as the quantity and type of nitrogen fertilizers, crop types, soil types, climate, and other environmental conditions.

Methodological Issues

The methodology used to estimate N_2O emissions is an IPCC Tier 1 methodology. Emissions are calculated by multiplying fertilizer consumption by the non-volatilized fraction (available for nitrification and denitrification) and by an emission factor.

The amount of nitrogen applied is obtained from yearly fertilizer sales data, which are available from regional fertilizer associations (Korol, 2003). These data include the amount of fertilizer nitrogen sold by retailers on or before June 30 of the inventory year. It is assumed that all fertilizer sold after June 30 is used in the next inventory year.

The amount of applied nitrogen is reduced by 10% (IPCC default) to account for losses due to volatilization. The IPCC default emission factor of 0.0125 kg N_2O-N/kg N is then applied for all types of nitrogen fertilizers (IPCC/OECD/IEA, 1997).

Uncertainties and Time-Series Consistency

The uncertainty of synthetic fertilizer nitrogen consumption data is considered to be low (0–10%). The uncertainty associated with the IPCC default emission factor is expected to be moderate (±30%), particularly because of the relatively high degree of spatial and temporal variability associated with this emission process. The overall uncertainty associated with this emission estimate is expected to be moderate (-25% to +35%) (ICF, 2004).

The same methodology and emission factors are used for the entire time series (1990–2003).

QA/QC and Verification

This category has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2000). The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form.

N_2O emissions associated with synthetic fertilizer nitrogen applications on agricultural soils in Canada vary widely. However, at regional and national scales, there is close agreement between the aggregated, measured emission factor and the IPCC default value.

Recalculations

No recalculations have been carried out.

Planned Improvements

The potential use of IPCC Tier 2 methodology with a country-specific emission factor is being investigated.

6.3.1.2 Animal Manure Applied to Soils

Source Category Description

The application of animal manure as fertilizer to soils can increase the rate of nitrification/denitrification and result in enhanced N_2O emissions from agricultural soils. Note that emissions from this category include manure managed by drylot, liquid, and other AWMS. Manure deposited on grazing land is included in Section 6.3.1.6, Manure on Pasture and Paddock.

Methodological Issues

The methodology used to estimate these N_2O emissions is an IPCC Tier 1 methodology. Emissions are calculated by multiplying the amount of manure nitrogen applied to agricultural soils by the non-volatilized fraction (available for nitrification and denitrification) and by an emission factor. All manure that is handled by the AWMS, except for the manure on pasture and paddock from grazing animals, is assumed to be applied to agricultural soils (see Section 6.2).

The amount of manure nitrogen excreted is reduced by the IPCC default value, 20%, to account for the volatilization of NH_3 and NO_x (IPCC/OECD/IEA, 1997). The IPCC default emission factor (0.0125 kg N_2O-N/kg N) is adopted for Canada (IPCC/OECD/IEA, 1997).

Uncertainties and Time-Series Consistency

There is a moderate degree of uncertainty associated with the quantity of manure nitrogen applied to agricultural soils (±20%). The uncertainty associated with the emission factor adopted from the IPCC default to produce emission estimates is also expected to be moderate (±30%). The overall uncertainty associated with emission estimates from this source is moderate (-30% to +35%) (ICF, 2004).

The same methodology and emission factors are used for the entire time series (1990–2003).

QA/QC and Verification

This category has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2000). The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form.

Recalculations

Recalculations have been carried out because of the addition of buffaloes, the revision in the goat population from 1990 to 1995, the revision to the poultry population data, as well as the change in percentage of manure nitrogen handled by AWMS. In addition, as a part of implementation of IPCC (2000), the equation for calculating N_2O resulting from animal manure applied as fertilizers has been changed from the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997). Overall, these recalculations decreased the reported 1990 emissions by 0.42 Mt and the 2002 emissions by 0.72 Mt, compared with the 2004 submission, but have had a minimal impact on the long-term trend.

The revision of the poultry population resulted in a downward revision of N_2O emissions of 0.6 Mt in 1990 and 0.91 Mt in 2002. Changing the equation from IPCC/OECD/IEA (1997) to IPCC (2000) for calculating N_2O emissions resulting from animal manure applied as fertilizers resulted in an upward revision of emissions by approximately 0.17 Mt in 1990 and 0.19 Mt in 2002. The addition of buffaloes, the revision in the goat population from 1990 to 1995, and the change in percentage of manure nitrogen handled by AWMS had a relatively smaller impact on the change in N_2O emissions from this source.

Planned Improvements

The possibility of deriving national direct N_2O emission estimates with Tier 2 country-specific emission factors is currently being investigated.

6.3.1.3 Nitrogen-Fixing Crops

Source Category Description

Atmospheric nitrogen fixed by nitrogen-fixing crops (e.g., peas, lentils, beans, and alfalfa) can undergo the process of nitrification and denitrification in the same manner as nitrogen applied as synthetic fertilizer. Also, rhizobia in the plant nodules can emit N_2O as they fix nitrogen.

Methodological Issues

The methodology used for estimating emissions is an IPCC Tier 1 methodology. Emissions are calculated by multiplying the dry matter of nitrogen-fixing crops by the nitrogen content and by an N_2O emission factor.

The IPCC default value for the average dry matter fraction (i.e., 86%) is applied to wheat, barley, corn, oats, rye, peas, beans, soybean, lentils, and tame hay crops (IPCC/OECD/IEA, 1997). Silage corn, potatoes, and sugar beets are assumed to contain 30, 25, and 20% dry mass, respectively. As annual statistics for alfalfa production are combined with tame hay production, alfalfa quantities are estimated by assuming that 60% of tame hay production is alfalfa. In addition, the crop mass of alfalfa and tame hay is assumed to be equal to the reported production. The other crop production data are obtained from Statistics Canada (2003a).

The amount of nitrogen in the nitrogen-fixing crops is estimated from production data, assuming that the crop mass is twice the mass of the edible portion and that it contains 0.03 kg N/kg dry mass (IPCC/OECD/IEA, 1997). The IPCC default emission factor (0.0125 kg N_2O-N/kg N) for the nitrogen contained in nitrogen-fixing crops is applied (IPCC/OECD/IEA, 1997).

Uncertainties and Time-Series Consistency

The quality of crop production data is generally high (1–5%). The uncertainty associated with the IPCC default nitrogen concentration for all nitrogen-fixing crops is ±20%. The uncertainty associated with the IPCC default emission factor for nitrogen-fixing crops is expected to be moderate (±30%). The overall uncertainty associated with this source of emission estimates is expected to be moderate (-35% to +50%) (ICF, 2004).

There has been very little scientific work in quantifying N_2O emissions associated with biological nitrogen fixation in Canada or elsewhere. The current Revised 1996 IPCC Guidelines (IPCC/OECS/IEA, 1997) accounting for this particular emission source reflect general understanding of soil nitrogen cycling, rather than actual scientific measurements. Furthermore, estimates of nitrogen contained in leguminous crops based on the IPCC guidelines are considered to be very crude.

The same methodology and emission factors are used for the entire time series (1990–2003).

QA/QC and Verification

This category has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2000). The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form.

Environment Canada has supported a two-year research initiative, "Quantifying nitrous oxide emissions resulting from the production of leguminous crops in Canada" (Lemke et al., 2003; Rochette et al., 2003). The objective of this study was to quantify emissions of N_2O resulting from leguminous crop production in Canada. The results from this research, comparing leguminous with non-leguminous crops, show that there was no significant emission of N_2O during the growing season, which suggests that this source of emissions may have been overestimated.

Recalculations

No recalculations have been carried out.

Planned Improvements

There is no current plan in place aimed at improving the emission estimate from this source.

6.3.1.4 Crop Residue Decomposition

Source Category Description

When a crop is harvested, a portion of the crop (crop residue) is left on the field to decompose. The remaining plant matter is a nitrogen source for nitrification and denitrification processes and thus produces N_2O. In some cases, the remaining crop residue is burned, but it is assumed that the amount of burning is negligible in Canada.

Methodological Issues

Emissions are estimated using the IPCC Tier 1 methodology as follows: the amount of nitrogen contained in crop residues from both nitrogen-fixing and non-nitrogen-fixing crops is multiplied by an N_2O emission factor.

The nitrogen contents for nitrogen-fixing crop residue, 0.03 kg N/dry kg, and other crops, 0.015 kg N/dry kg, are adopted for Canada (IPCC/OECD/IEA, 1997). The crop dry mass is estimated using the average dry matter fractions from IPCC/OECD/IEA (1997). The IPCC default emission factor of 0.0125 kg N_2O-N/kg N (IPCC/OECD/IEA, 1997) is then applied.

Uncertainties and Time-Series Consistency

The uncertainties are due to the uncertainties associated with the quantity of nitrogen contained in the crop residues and the emission factor adopted from the IPCC guidelines (IPCC/OECD/IEA, 1997). The uncertainty associated with the quantity of nitrogen contained in the crop residues is expected to be moderate (±30%). The uncertainty associated with the IPCC default emission factor for crop residue decomposition is also expected to be moderate (±30%). The overall uncertainties associated with N_2O emissions from crop residue decomposition vary from -40% to +55% (ICF, 2004).

There has been very little scientific work on quantifying emissions of N_2O associated with crop residue decomposition in Canada and elsewhere. The current Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) reflect the general understanding of soil nitrogen cycling, rather than actual scientific measurements.

The same methodology and emission factors are used for the entire time series (1990–2003).

QA/QC and Verification

This category has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2000). The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form.

Recalculations

No recalculations have been carried out.

Planned Improvements

Estimates of nitrogen contained in crops can be improved using specific harvest indices and nitrogen content. Canada is working towards the adoption of IPCC Tier 1b methodology (IPCC, 2000) for estimating this source of emission.

6.3.1.5 Cultivation of Organic Soils (Histosols)

Source Category Description

Cultivation of organic soils (histosols) for crop production usually involves drainage, lowering the belowground water table, increasing aeration, and speeding up the decomposition of organic matter. Denitrification and nitrification also take place, releasing N_2O emissions.

Methodological Issues

The IPCC Tier 1 methodology is used to estimate N_2O emissions from cultivated organic soils. N_2O emissions are calculated by multiplying the area of cultivated histosols by an emission factor. The emission factor of 5 kg N_2O/ha per year has been replaced by 8 kg N_2O/ha per year as a part of implementation of the IPCC Good Practice Guidance (IPCC, 2000).

Areas of cultivated histosols at a provincial level are not covered in the Census of Agriculture, which is carried out regularly at five-year intervals by Statistics Canada. In the absence of these data, consultations with numerous soil and crop specialists across Canada have been made. The total area of cultivated organic soils in Canada has been updated to 15 654 ha for the period 1990–2003 (G. Padbury and G. Patterson, personal communication).

Uncertainties and Time-Series Consistency

Uncertainties associated with the area of cultivated histosols and the emission factor are ±20% and ±30%, respectively. The overall uncertainty associated with emission estimates for cultivation of histosols is ±35% (ICF, 2004).

The same methodology and emission factors are used for the entire time series (1990–2003).

QA/QC and Verification

This category has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2000). The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form.

Recalculations

Recalculations have been carried out because of changes in the area of cultivated organic soils in Canada as well as the change in emission factor as adopted from IPCC (2000).

The area of cultivated organic soils for annual crop production in Canada has been revised from 29 802 ha to 15 654 ha based on recent consultations with federal and provincial crop and soil specialists. The changes in the area estimate and emission factor reduced the emissions from 0.07 Mt (previously reported) to 0.06 Mt annually.

Planned Improvements

There is no immediate plan in place aimed at improving emission estimates from this source.

6.3.1.6 Manure on Pasture and Paddock

Source Category Description

When manure is excreted on pasture and paddock from grazing animals, nitrogen in the manure undergoes transformations (i.e., ammonification, nitrification, and denitrification). During these transformation processes, N_2O is produced.

Methodological Issues

The emissions from manure excreted by grazing animals are calculated using the IPCC Tier 1 methodology (IPCC/OECD/IEA, 1997). Emissions are calculated for each animal category by multiplying the animal population by the appropriate nitrogen excretion rate and by the fraction of manure nitrogen available for conversion to N_2O.

The animal population data are the same as those used in Section 6.2. The nitrogen excretion rates are based on research conducted in the United States (ASAE, 1999). The fraction of manure nitrogen available for conversion to N_2O is calculated as the percentage of total manure nitrogen produced on pasture and paddock multiplied by the IPCC default value of 0.02 kg N_2O-N/kg N, which represents the fraction of excreted manure nitrogen converted to N_2O.

Uncertainties and Time-Series Consistency

Uncertainties associated with emission estimates from this source include animal populations (0–15%), animal nitrogen excretion rates (±30%), proportion of manure nitrogen excreted on pasture and paddock (±20%), and the emission factor (±30%). The overall uncertainty associated with this source of emission estimates varies from -35% to +45% (ICF, 2004).

The same methodology and emission factors are used for the entire time series (1990–2003).

QA/QC and Verification

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors. In general, there are very few data available on the quantity of N_2O emissions from the manure on pasture and paddock from grazing animals in Canada. Therefore, it is extremely difficult to verify how well the IPCC emission factor reflects Canadian conditions.

Recalculations

Recalculations have been carried out because of the addition of buffaloes, the revision in the goat population from 1990 to 1995, the changes to the poultry population accounts, and the change in the proportion of manure nitrogen excreted on pasture and paddock. Overall, these recalculations increased the reported 1990 emissions by 0.27 Mt and the 2002 emissions by 0.38 Mt, compared with the 2004 submission, but have had a minimal impact on the long-term trend.

Planned Improvements

Due to recent advances in measuring N_2O fluxes using flux chambers and flux towers, it is expected that country-specific data on N_2O emissions from manure on pasture and paddock will be available over the next few years in Canada.

6.3.2 INDIRECT EMISSIONS OF NITROUS OXIDE FROM SOILS (CRF CATEGORY 4.D.2)

A fraction of the fertilizer nitrogen (from both synthetic fertilizer and manure) that is applied to agricultural fields will be transported off site through either volatilization and subsequent redeposition or leaching, erosion, and runoff. The nitrogen that is transported from the agricultural field in this manner will provide additional nitrogen for subsequent nitrification and denitrification to produce N_2O.

Note that the nitrogen leaving an agricultural field may not be available for the process of nitrification and denitrification for many years, particularly in the case of nitrogen leaching into groundwater.

6.3.2.1 Volatilization and Redeposition of Nitrogen

Source Category Description

When synthetic fertilizer or manure is applied on cropland, a portion of this nitrogen is lost through volatilization in the form of NH_3 or NO_x. This volatilized nitrogen can be redeposited somewhere else and can undergo further transformations such as nitrification and denitrification, thus resulting in N_2O emissions off site. The quantity of this volatilized nitrogen depends on a number of factors, such as rates, fertilizer types, methods and time of nitrogen application, soil texture, rainfall, temperature, soil pH, etc.

Methodological Issues

The IPCC Tier 1 methodology is used to estimate indirect N_2O emissions due to volatilization and redeposition of nitrogen from applied synthetic fertilizer and manure (IPCC/OECD/IEA, 1997). The amount of synthetic fertilizer consumption is multiplied by the fraction of nitrogen that is volatilized as NH_3 and NO_x and then by an emission factor. The amount of nitrogen applied is obtained from yearly fertilizer sales data, which are available from regional fertilizer associations (Korol, 2003). The amount of nitrogen that volatilizes is assumed to be 10% of synthetic fertilizer applied and 20% of manure nitrogen applied. The same IPCC emission factor, 0.01 kg N_2O-N/kg N, is applied to derive the N_2O emission estimate (IPCC/OECD/IEA, 1997).

Uncertainties and Time-Series Consistency

The uncertainty associated with the estimate of the fraction of nitrogen that is lost through volatilization of NH_3 and NO_x is estimated to be ±20%. A very high level of uncertainty associated with the emission factor is assigned (-100% to 150%). Emission estimates from this source determined using Monte Carlo simulations (ICF, 2004) vary from -75% to 130%.

It is extremely difficult to verify how well the IPCC emission factor reflects Canadian conditions. The methodology in the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) for this particular source of N_2O is more conceptual, based on general principles of nitrogen cycling, rather than actual measurement of emissions. In fact, there is no established experimental protocol for determining an emission factor from volatilization of fertilizer and manure nitrogen and subsequent redeposition.

The same methodology and emission factors are used for the entire time series (1990–2003).

QA/QC and Verification

This category has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2000). The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form.

Recalculations

Recalculations have been carried out because of the addition of buffaloes, the change in the goat population from 1990 to 1995, and the revision of the poultry population figures. Overall, these recalculations decreased the reported 1990 emissions by 0.1 Mt and the 2002 emissions by 0.2 Mt, compared with the 2004 submission, but have had a minimal impact on the long-term trend.

The revision of the poultry population resulted in a reduction of the N_2O emissions by 0.1 Mt in 1990 and by 0.2 Mt in 2002. The addition of buffaloes and the revision of the goat population from 1990 to 1995 had a smaller impact on the emissions.

Planned Improvements

There are no immediate plans aimed at improving emission estimates from this source.

6.3.2.2 Leaching, Erosion, and Runoff

Source Category Description

When synthetic fertilizer or manure nitrogen is applied to cropland, a portion of this nitrogen is lost through leaching, erosion, and runoff. The quantity of this nitrogen loss depends on a number of factors, such as rates, methods, and time of nitrogen application, crop type, soil texture, rainfall, landscape, etc. This portion of lost nitrogen can further undergo transformations, such as nitrification and denitrification, thus producing N_2O emissions off site.

Methodological Issues

The IPCC methodology estimates N_2O emissions from runoff and leaching of nitrogen by assuming that 30% of the nitrogen applied as synthetic fertilizer or manure is lost by leaching or runoff and multiplies this by 0.025 kg N_2O-N/kg N leaching/runoff to obtain an emission estimate (IPCC/OECD/IEA, 1997).

For the reasons described below, Canada has adopted a country-specific leaching factor instead of the IPCC default. This method reflects the low precipitation and high evaporation conditions that occur on the Canadian prairies, where more than 80% of Canada's agricultural land is located and where most fertilizer is consumed. The emissions from runoff and leaching are estimated by assuming that 15% of the nitrogen applied as synthetic fertilizer or manure is lost through leaching and runoff.

In Canada, leaching losses of nitrogen vary widely among regions. High nitrogen inputs in humid conditions may lead to leaching losses greater than 100 kg N/ha per year in some farming systems of southern British Columbia (Paul and Zebarth, 1997; Zebarth et al., 1998). Such losses, however, represent only a small fraction of Canadian agroecosystems. In Ontario, Goss and Goorahoo (1995) predicted leaching losses of 0–37 kg N/ha, accounting for 0–20% of nitrogen inputs from seed, feed, fertilizer, manure, animals, biological nitrogen fixation, and atmospheric deposition. Leaching losses in most of the prairie region may be smaller because of lower precipitation and nitrogen inputs. Nyborg et al. (1995) suggested that leaching losses were minimal from a long-term experiment in central Alberta, and Chang and Janzen (1996) found no evidence of nitrogen leaching in non-irrigated, heavily manured plots, despite large accumulations of soil nitrate in the soil profile. In the Prairie provinces of western Canada, which account for more than 80% of fertilizer inputs and agricultural land in Canada, potential evaporation exceeds precipitation by a large margin (Reynolds et al., 1995). Therefore, leaching losses in Canada are probably lower than in many other countries with intensive agriculture.

Uncertainties and Time-Series Consistency

A very high level of uncertainty is associated with estimates of emissions from this indirect source because there is a high degree of uncertainty associated with estimates of the quantity of fertilizer- and manure-nitrogen leached from agricultural soils in a form of NO_3^- (±50%) as well as the emission factor (-100% to +150%). Emission estimates from this source determined using Monte Carlo simulations vary from -70% to +150% (ICF, 2004).

The methodology of the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) for this particular source of N_2O emissions is more conceptual, based on general principles of nitrogen cycling, rather than actual measurement of emissions. In fact, there is no established experimental protocol for determining an emission factor from runoff, leaching, and erosion.

The same methodology and emission factors are used for the entire time series (1990–2003).

QA/QC and Verification

This category has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2000). The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form.

Recalculations

Recalculations have been carried out because of the addition of buffaloes in the animal categories, the change in the goat population from 1990 to 1995, and the change in poultry population data. Overall, these recalculations decreased the reported 1990 emissions by 0.2 Mt and the 2002 emissions by 0.3 Mt, compared with the 2004 submission, but have had a minimal impact on the long-term trend.

Planned Improvements

There are no immediate plans aimed at improving emission estimates from this source.

7 LAND USE, LAND-USE CHANGE AND FORESTRY (CRF SECTOR 5)

OVERVIEW

The LULUCF Sector reports GHG fluxes between the atmosphere and Canada's managed lands, as well as those associated with changes in the way in which land is used. To comply with the new LULUCF reporting format, CO_2 fluxes to and from agricultural soils are now reported in this sector (see section below, "New Reporting Format"). In keeping with the IPCC guidelines, the methodology emphasizes human, or anthropogenic, impacts on the national GHG balance.

The assessment includes CO_2 emissions and removals and, in the case of forest fires, emissions of the non-CO_2 gases CH_4, N_2O, NO_x, and CO. Based on Canada's understanding of Decision 13/CP.9 of the Ninth Conference of the Parties to the UNFCCC, all emissions and removals in the LULUCF Sector are excluded from the national totals. This differs from previous reports where non-CO_2 emissions from the LULUCF Sector were included in national totals.

In 2003, the net GHG flux from the LULUCF Sector, calculated as the sum of CO_2 emissions and removals and non-CO_2 emissions, amounted to a removal of 44 Mt. If it were included in the national total, this flux would decrease the total Canadian GHG emissions by 9%. The net CO_2 flux alone, estimated as a net removal of nearly 46 Mt, dominates the pattern of emissions and removals.

Table 7-1 provides net flux estimates for the base and most recent years in all the major LULUCF Sector categories and subcategories. In view of the high interannual variability displayed by some LULUCF Sector categories, the reader is cautioned against interpreting these figures as trends. The full-time series of LULUCF estimates is available in Table 10 of the CRF series for the 2003 inventory year.

TABLE 7-1: **LULUCF Sector Net GHG Flux Estimates for Selected Years**

		kt CO_2 eq	
GHG Source/Sink Categories	**1990**	**2002**	**2003**
Land Use, Land-Use Change and Forestry TOTAL	**-150 000**	**-33 000**	**-44 000**
a. Forest Land	**-190 000**	**-58 000**	**-69 000**
Forest Land Remaining Forest Land	-190 000	-57 000	-68 000
Land Converted to Forest Land	-1 000	-1 000	-1 000
b. Cropland	**23 000**	**15 000**	**14 000**
Cropland Remaining Cropland	7 200	-980	-1 500
Land Converted to Cropland	16 000	16 000	16 000
c. Grassland	**5 000**	**5 000**	**5 000**
Grassland Remaining Grassland	–	–	–
Land Converted to Grassland	5 000	5 000	5 000
d. Wetlands	**–**	**–**	**–**
e. Settlements	**6 000**	**6 000**	**6 000**
Settlements Remaining Settlements	-100	-200	-200
Land Converted to Settlements	6 000	6 000	6 000

Of all LULUCF Sector categories, Forest Land generally displays the largest fluxes. It also remains a net sink throughout the reporting period. However, the magnitude of these net removals fluctuates annually. In all years except 1995, removals in the Forest Land category exceed the combined emissions of all other LULUCF Sector categories, resulting in net removals at the sector level. In 1995, a year of devastating forest fires, net Forest Land removals were smaller than the other sources combined; for this year, the LULUCF Sector was a net source. Although there are large uncertainties attached to all LULUCF Sector estimates and the resulting net sectoral balance, this pattern illustrates well how the interplay of natural disturbances and management activities ultimately affects the net GHG balance of the sector.

As explained in more detail throughout this chapter, Canada is engaged in a multi-year effort to substantially improve its LULUCF Sector estimates. A process has been established for the development of a national framework for the monitoring, accounting, and reporting of GHG emissions/removals from Canada's managed lands, with guidance from the interdepartmental Steering Committee of MARS for LULUCF. The framework provides a means for coordinating, planning, and integrating the activities of Environment Canada and the other government departments, research groups, and agencies involved in the GHG inventory development.

The planned improvements require significant changes in the inventory preparation procedures, the integration of multi-governmental initiatives, and active collaboration among the many stakeholders in the Canadian land management community, so full implementation will take several years. In light of this situation, the approaches, methods, and estimates reported in this submission should be considered transitory, pending consolidation and implementation of the efforts currently under way. Substantial improvements are expected as a result of this multi-year process, and significant recalculations will continue over the next several years as the efforts under way are implemented. Canada recognizes that these ongoing changes may create some confusion, but has decided that, to facilitate transparency, changes would be implemented on an ongoing basis rather than all at once.

NEW REPORTING FORMAT

In 2005, the LULUCF Sector is implementing on a trial basis the new reporting format adopted by the Ninth Conference of the Parties to the UNFCCC, based on the IPCC *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003). In this format, LULUCF emissions to the atmosphere from sources and removals by sinks are estimated and reported for five main categories of managed lands: Forest Land, Cropland, Grassland, Wetlands, and Settlements. As shown in Table 7-1 above, each category is divided into lands that have remained in this category during the inventory year and lands newly brought under the category. A seventh category, "Other Land," allows verification of the consistency of total land areas, but does not necessarily entail any GHG reporting obligations, unless it comprises areas of managed lands not included in the other categories.

The major purpose of the new reporting format is to facilitate the consistent representation of land areas — i.e., prevent double-counting of land areas and ensure that all land areas are represented (IPCC, 2003: Chapter 2). As such, the new reporting format represents more than a restructuring of the information; it calls for the development of several new GHG estimates, notably in the Grassland, Wetlands, and Settlements categories. The implementation of the IPCC (2003) report also entails that all land management activities represented in the LULUCF Sector be associated with a spatial attribute and that these attributes be reconciled, which involves significant enhancements in estimation procedures. The ongoing development of Canada's LULUCF inventory system, briefly outlined in the Overview section above, aims to address most of these new requirements. Until its full implementation, and especially for this trial year, estimates were simply reassigned to the corresponding new LULUCF Sector category and will not provide the desired spatial consistency or fulfill all the new reporting requirements created by the IPCC Good Practice Guidance report (IPCC, 2003).

Table 7-2 provides a crosswalk of the 2003 LULUCF estimates and the equivalents that would have been reported in the former LUCF categories. The difference of 1500 kt in the sectoral total is due to the reporting of CO_2 removals by agricultural soils in the LULUCF Sector (whereas they were previously reported in the Agriculture Sector). Special care was taken so as not to double-count emissions from the Agriculture Sector of the inventory.

The conversion of forest and grassland to other land uses, singled out in the former LUCF Sector, is not explicitly identified in the new LULUCF reporting format. It is nevertheless reported as a memo item in Table 5 of the CRF. Preliminary estimates of deforestation in Canada suggest that forest losses to cropland, grassland, and urbanization amount to annual emissions of about 17 Mt.

Estimation of GHG emissions and removals from (managed) grassland remaining grassland and land conversion to wetlands and N_2O emissions from disturbance associated with land-use conversion to cropland are new reporting requirements under the UNFCCC (IPCC, 2003). Canada has not yet developed estimates in these categories. N_2O emissions from drainage of forest lands are not reported, as this practice is believed not to be occurring. N_2O emissions from nitrogen fertilization of forest land cannot at this point be separated from those resulting from the use of fertilizers on agricultural lands, which are

TABLE 7-2: 2003 GHG Estimates in the Former LUCF and New LULUCF Reporting Formats

"New" LULUCF Categories	kt CO_2 eq Net flux	"Old" LUCF Categories	kt CO_2 eq Net flux
TOTAL	**-44 000**	**TOTAL**	**-42 000**
Forest Land			
Forest Land Remaining Forest Land	-68 000	Changes in Forest and Other Biomass Stocks	-68 000
Land Converted to Forest Land	-1 000	Abandonment of Managed Lands (5C) +	-750
		Emissions and Removals from Soils (5D)	-260
Cropland			
Cropland Remaining Cropland	-1 500	[Reported in the Agriculture Sector]	–
Land Converted to Cropland	16 000	Forest and Grassland Conversion (5B) +	5 600
		Emissions and Removals from Soils (5D)	10 000
Grassland			
Grassland Remaining Grassland	–		–
Land Converted to Grassland	5 000	Forest and Grassland Conversion (5B)	5 000
Wetlands	–		–
Settlements			
Settlements Remaining Settlements	-200	Changes in Forest and Other Biomass Stocks (Urban Trees)	-200
Land Converted to Settlements	6 000	Forest and Grassland Conversion (5B) +	2 000
		Emissions and Removals from Soils (5D)	4 000

estimated based on total fertilizer use in Canadian provinces. The quantity of fertilizer applied on forest lands is insignificant in relation to its use in agricultural management practices.

Note that removals of 200 kt per year by urban trees and forests, reported under "Settlements Remaining Settlements," were previously reported under the LUCF category "Changes in Forest and Other Biomass Stocks."

Table 5 of the CRF allows reporting estimates of emissions or removals from harvested wood products (HWP) that presumably are additional to the Forest Land estimates. Canada considers that this reporting format is not compatible with its understanding of HWP as an integral component of the Forest Land category. Alternative estimates of delayed emissions due to carbon storage in HWP are provided in Section A3.2 of Annex 3.

The remainder of this chapter is divided into four sections: Forest Land Remaining Forest Land, Cropland Remaining Cropland, Other LULUCF Categories, and Land Conversion. While not strictly consistent with the LULUCF structure, this configuration prevents a repetitive discussion of the several issues common to the estimation and reporting of land-use change.

7.1 FOREST LAND REMAINING FOREST LAND

7.1.1 SOURCE CATEGORY DESCRIPTION

The IPCC Forest Land category is composed of Forest Land Remaining Forest Land and Land Converted to Forest Land. The former represents 99% of GHG fluxes in this category and is the main subject of this section. The estimation of GHG fluxes due to land conversion to forest land is covered in Section 7.4 below, "Land Conversion."

The 2001 update of Canada's Forest Inventory (CanFI, 2001) shows a total area of forest and other wooded land of 402 Mha, composed of a mosaic of ecosystems, with forests of different ages and species composition exposed to various climates and disturbance regimes. Approximately 214 Mha, or 53% of the total area of forest and other wooded land, are considered forests under direct human influence and, for the purpose of this inventory, represent the "managed forests." These forests are classified as non-reserved and are either included in a management inventory or accessible by road. Details on the use of forest inventory information can be found in Section A3.2. Forests that are reserved for other uses (parks and reserves) or are non-accessible and non-inventoried are excluded from this assessment.

In 2003, the area of managed forests assumed to be actively sequestering carbon in the aboveground biomass occupied 65% of the managed forest area, or approximately 138 Mha, of which 91 Mha (66%) lie in the boreal region (CRF Table 5A). During that period, the net GHG balance of managed forests amounted to removals of 68 Mt (Table 7-2 above and CRF Table 5).

7.1.2 METHODOLOGICAL ISSUES

Vegetation absorbs CO_2 from the atmosphere through photosynthesis, and some of this carbon is sequestered in standing vegetation, dead biomass, and soils. CO_2 is returned to the atmosphere by vegetation respiration and the decay of organic matter in dead biomass and soils. The natural CO_2 exchanges between the atmosphere and biota are large fluxes, recycling on the order of one-seventh of the total atmospheric CO_2 content annually. In reality, these large fluxes result from the accumulation of minute processes dispersed over vast land areas.

Human interactions with the land directly alter the size and rate of these natural exchanges of GHGs, in both the immediate and long term. Land-use changes and land-use practices in the past still affect current GHG fluxes to and from the terrestrial biosphere. This long-term effect is a unique characteristic of the LULUCF Sector, which makes it very distinct from other sectors, such as Energy.

While the focus is on anthropogenic impacts on the GHG balance, it is recognized that separating human from natural effects in the LULUCF Sector poses a unique challenge. Humans manipulate biological processes in a myriad of ways and intensities. What we observe is typically the outcome of these various manipulations and their combined interactions with an equally varied biophysical environment. Untangling the various cause-and-effect relationships is still the object of complex scientific inquiries.

Canada's large land mass and decentralized land management systems add to the challenges of assessing the associated GHG emissions and removals. Not all Canadian forests are under the direct influence of human activities — prompting the non-trivial question of what areas properly embody the "managed" forestlands. To date, the managed forests have never been formally defined in Canada; hence, an operational, proxy definition was derived from forest inventory classifiers. To improve the consistency of managed forest estimates, the need for an agreed-upon, spatial definition is recognized. An extensive consultation process, involving the 13 provincial and territorial forest management agencies and the Canadian Forest Service, is currently under way to revise the Canadian implementation of the "managed forests" category for UNFCCC reporting.

Canada uses a Tier 2 methodology for estimating GHG emissions and removals on managed forest land, based on the approach developed in the IPCC guidelines (IPCC/OECD/IEA, 1997) and elaborated in the IPCC Good Practice Report (IPCC, 2003: Chapter 3, Equations 3.2.4 to 3.2.9). Net removals or emissions are calculated as the difference between CO_2 uptake through forest tree growth and emissions resulting from commercial forest management (harvested roundwood, fuelwood collection, and site preparation with prescribed burning) and domestic firewood collection. Due to their predominant role in the ecology and stand dynamics of Canadian forests, wildfires have also been included in the GHG balance of the managed forests. All GHG emissions from fires in the managed forests are reported in CRF Table 5(V).

The estimation procedures generally rely on parameter values that are country-specific. Note that, due to current limitations of the available information and knowledge on managed forests, the estimation is limited to the aboveground biomass carbon pool. Other gaps include the effects of stand-replacing insect infestations or epidemics. The discussion on uncertainty below elaborates on the implications of these omissions. Section A3.2 provides a more detailed account of the estimation methods.

In keeping with the current IPCC default methodology (IPCC, 2003), emissions from forest management activities comprise all the CO_2-C contained in harvested roundwood and harvest residues. Three alternative approaches — atmospheric flow, production, and stock change — have been preliminarily evaluated in Canada to attempt to correctly account for delayed emissions due to long-term carbon storage in HWPs. These approaches account for carbon storage in HWPs and emissions from the decay of products harvested, imported (stock change, atmospheric flow), or exported (production) in the current and previous years; they are therefore more spatially and temporally realistic than the current default, which does not account for emissions from HWPs where or when they actually occur. They differ with respect to their allocation of emissions and removals. A breakdown and brief discussion of each of the accounting approaches, along with implications for Canada, are contained in Section A3.2.

7.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The UNFCCC Reporting Guidelines identify four major sources of uncertainty, which all apply to the LULUCF Sector. These are definitions, methodology, activity data, and underlying scientific understanding. A major source of uncertainty is the temporary values so far ascribed to the managed forest areas — i.e., 214 Mha in this report, based on available forest inventory information. There is a high probability that the forest area under direct human influence varies significantly from 214 Mha.

On the methodological side, the main source of uncertainty is the omission from the estimation methodology of important carbon pools such as forest soils, dead organic matter, and HWPs. In order to include other forest ecosystem carbon pools (belowground biomass, litter, coarse debris, and soils) without introducing bias, all the carbon exchanges among these pools, and between each one and the atmosphere, should be estimated. For example, using default root: shoot ratios (IPCC, 2003: Table 3A1.8 and Equation 3.2.5) without supplementary data on belowground carbon turnover and decay would result in a gross overestimate of net carbon sequestration in forests. The nature of this uncertainty is such that it is not possible at this time to conduct a quantitative uncertainty assessment on emission and removal estimates.

The second most important source of uncertainty associated with both methodology and data results from the use of highly aggregated, spatially coarse forest data, notably the mean annual increments, biomass expansion factors, harvest areas, and areas burned.

Notwithstanding forest fires, the impact of all other stand-replacing disturbances is excluded from this assessment, although they do affect large areas. For example, entire tree populations may slowly die after repeated defoliation (e.g., by Spruce Budworm *Choristoneura fumiferana*) or following epidemics of wood-boring insects (e.g., Mountain Pine Beetle *Dendroctonus ponderosae)*. The impact of these disturbances on emissions to the atmosphere is less immediate than that of fires, since the carbon would primarily be transferred to the dead organic matter and soil carbon pools and oxidize over a period of several years or decades.

Work is under way to address these definitional and methodological deficiencies, data gaps, and scientific uncertainty, as described in Section 7.1.6 (Planned Improvements).

7.1.4 QA/QC AND VERIFICATION

Being a key category, Forest Land Remaining Forest Land has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2003). The activity data, methodologies, changes, and QC checks are documented and archived in both paper and electronic form.

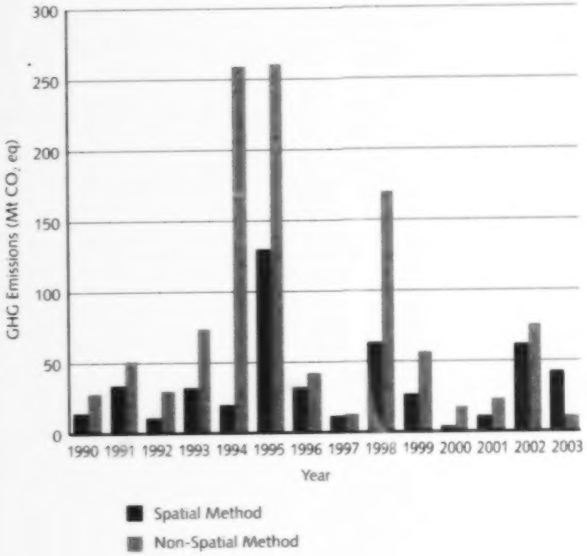
In addition, the LULUCF Sector has already developed a manual describing the current LULUCF inventory preparation procedures (Henderson and Blain, 2003).

7.1.5 RECALCULATIONS

Significant recalculations were conducted in the estimation of the areas burned annually by wildfires in managed forests. The revised approach is based on a spatial overlay of the boundaries of the Forest Inventory spatial units, with polygons indicating the geographical location and extent of large forest fires. The aim was to reduce the uncertainty of the location of wildfires with respect to the managed forests. This analysis yielded substantially revised estimates of the forest area burned annually in the managed forests (Section A3.2, Table A3-21). These revised estimates had a double effect: smaller areas of temporarily non-stocked forests due to disturbances; and lower direct GHG emissions from wildfires (Figure 7-1). Details on methods and sources of information are provided in Section A3.2, as is a discussion of the differences in the results for the previous non-spatial method and the new spatial method.

The other recalculations implemented in this submission involve data updates, as opposed to methodological changes. This submission incorporates CanFI (2001) data that were not available for the previous submission, resulting in a change of the total area of managed forests from 203 Mha (2004 submission) to 214 Mha (this submission). Other estimation procedures and parameters remain unaffected. The total area of managed forests is assumed to be constant

FIGURE 7-1: Direct GHG Emissions from Wildfires in the Managed Forests, Estimated with Non-Spatial and Spatial (2005 submission) Methods



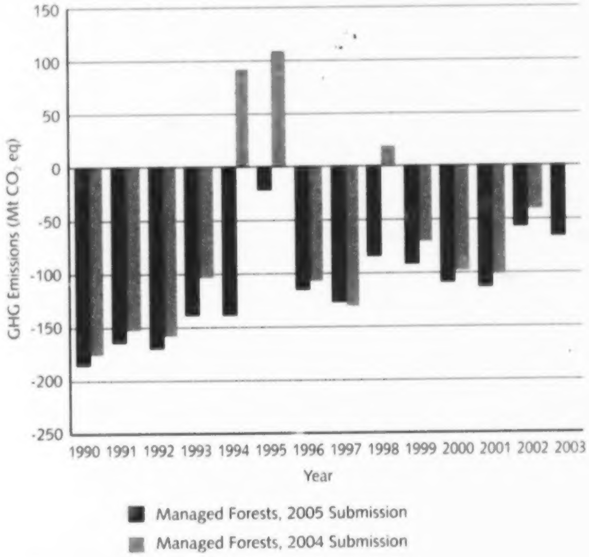
throughout the 1990–2003 period; the area that is stocked and actively sequestering carbon is evolving on an annual basis.

Figure 7-2 compares the time series of LUCF category 5A estimates (Changes in Forest and Other Biomass Stocks) submitted in 2004 with the current time series of the LULUCF category "Forest Land Remaining Forest Land." The comparison includes the combined effects of all recalculations and the minor change due to the reporting of urban tree growth under the LULUCF "Settlements" category.

7.1.6 PLANNED IMPROVEMENTS

As noted at the beginning of this chapter, Canada is engaged in a multi-year effort to substantially improve its LULUCF Sector estimates. Under the direction of the inter-departmental Forestry Working Group of the MARS–LULUCF, Canada is developing a GHG monitoring and reporting framework for forest lands (the National Forest Carbon Monitoring, Accounting and Reporting System) as part of the national framework for the GHG inventory of managed lands.

FIGURE 7-2: Net Flux from Managed Forests Reported in 2004 and 2005



In the Forest Land category, the short-term priority is to address the major uncertainties in the current estimates. To this end, the Carbon Budget Model of the Canadian Forest Sector, or CBM-CFS (Kurz et al., 1992; Kurz and Apps, 1999), is being further developed and adapted as an operational tool for national forest carbon monitoring (Kurz and Apps, in press) and is expected to be the major source of information for the preparation of LULUCF estimates for Forest Land under the UNFCCC and the Kyoto Protocol.

A spatially explicit version of CBM-CFS will allow the mapping of disturbances in relation to forest types. State-of-the-art knowledge will be integrated through science focus workshops that, to date, have been held on detection of change by remote sensing (Kurz et al., 2003a) and forest disturbances (Kurz et al., 2003b).

In the mid term, ongoing scientific and technical studies conducted in governments and universities will provide new knowledge and data to improve the representation of GHG dynamics in natural ecosystems and support validation and verification studies. Examples include the establishment of Fluxnet, a national research network of university and government scientists to study the influence of climate and disturbance on carbon cycling,[38] ongoing research under the auspices of the Sustainable Forest Management Network,[39] and a comprehensive database of forest ecosystem carbon distribution (Shaw et al., 2004). These efforts are expected to significantly enhance the inventory quality within the next few years.

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[38] See website: *www.fluxnet-canada.ca/*

In the future, the intent is to incorporate information from the new National Forest Inventory (NFI) (Anonymous, 1999) now being implemented. The NFI is based on permanent plots on a national grid, measured using agreed technical standards across provinces and territories, and will provide consistent and timely assessments of the extent and state of the forests. In the longer term, the implementation of Canada's new NFI will allow the derivation of consistent and accurate growth rates and provide the core infrastructure for the monitoring of Canada's forests.

7.2 CROPLAND REMAINING CROPLAND

The Cropland category is composed of Cropland Remaining Cropland and Land Converted to Cropland. The relative contribution of each category, the methodological issues and estimation procedures, and the trends differ significantly between categories and are discussed separately. This section covers the subcategory Cropland Remaining Cropland. The estimation of GHG fluxes due to land conversion to cropland is covered in Section 7.4 below, "Land Conversion."

7.2.1 SOURCE CATEGORY DESCRIPTION

Cultivation and management practices (e.g., tillage, crop rotation, fallow frequency, etc.) affect both carbon and nitrogen cycles in agricultural soils; they can lead to changes in soil organic carbon (SOC) and CO_2 emissions to or removals from the atmosphere. This section outlines the methodological issues associated with estimating CO_2 fluxes associated with the cultivation of mineral and organic soils and lime application.

Cultivated agricultural land in Canada includes field crop area plus summer-fallow. Approximately 80% of Canada's arable land is located in the three Prairie provinces of Alberta, Saskatchewan, and Manitoba. In Canada, cultivated organic soils are defined as the conversion of organic soils to agriculture for annual crop production, normally accompanied by artificial drainage, cultivation, and liming. Organic soils used for agriculture in Canada include the Peaty Phase of Gleysolic soils, Fibrisols over 60 cm thick, and Mesisols and Humisols over 40 cm thick.

7.2.2 METHODOLOGICAL ISSUES

This section briefly reviews the methodological issues related to the estimation procedures of CO_2 emissions and removals from cropland remaining cropland. The calculations and data sources are described in more detail in Section A3.2.

7.2.2.1 Cultivation of Mineral Soils

In Canada, CO_2 emissions from mineral soils have declined since 1990 due to changes in farming practices, such as no-till and reduction of summer-fallow in the prairies. No-till farming reduces the oxidation of SOC, while intensification of cropping systems (i.e., reducing summer-fallow) increases crop residue returned to the soil (Campbell et al., 1996; Janzen et al., 1998; McConkey et al., 2003). In the prairies, these two practices have been adopted simultaneously in many areas, thereby increasing the carbon stored in these soils: it is estimated that mineral soils are currently removing CO_2 from the atmosphere. No-till farming was practised on over 21% of Canada's cropland (i.e., summer-fallow plus land in crop) in 2001, 11% in 1996, and 5% in 1991 (Table 7-3) (Statistics Canada, 1992, 1997, 2002).

The Century model was used to estimate the rate of SOC change in agricultural soils in Canada, as developed by Smith et al. (1997). Section A3.2 provides a summary description of the approach, data sources, key parameter values, results, and limitations.

7.2.2.2 Lime Application

Limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) is often used to neutralize acidic mineral and organic soils, increase the availability of soil nutrients, in particular phosphorus, reduce the toxicity of heavy metals, such as Al^{3+}, and improve the crop growth environment.

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[39] See website: http://sfm-1.biology.ualberta.ca/

TABLE 7-3: **Agricultural Land Use in Canada, 1991–2001**

	Area *(Mha)*		
Agricultural Land Use	**1991**	**1996**	**2001**
Summer-fallow	7.92	6.26	4.68
Land in Crop	33.51	34.92	36.40
-No-till Land in Crop	1.95	4.59	8.82
Tame or Seeded Pasture	4.14	4.35	4.80
Natural Land for Pasture	15.96	15.61	15.39
Other	6.22	6.91	6.23
Total Agricultural Land	67.75	68.05	67.50

During this neutralization process, CO_2 is released in the following bicarbonate equilibrium reactions that take place in the soil:

$CaCO_3 + 2H^+ = CO_2 + Ca^{2+} + H_2O$

$CaMg(CO_3)_2 + 4H^+ = 2CO_2 + Ca^{2+} + Mg^{2+} + 2H_2O$

The rate of release will vary with soil conditions and the types of compounds applied. In most cases where lime is applied, applications are repeated every few years. For the purposes of the inventory, it was assumed that the rate of lime addition is in near equilibrium with the rate of lime consumed from previous applications.

Emissions associated with the use of lime can be calculated from the amount and composition of the lime applied annually, specifically the respective stoichiometric relationships that describe the breakdown of limestone and dolomite into CO_2 and other minerals. Estimates of CO_2 emissions from liming were done in 1996 (Sellers and Wellisch, 1998) and have been updated from 1997 to 2003. Methods and data sources are outlined in Section A3.2.

7.2.2.3 Cultivation of Organic Soils

The emissions from the cultivation of organic soils were calculated by multiplying the total area of cultivated histosols by a country-specific emission factor of 10 t CO_2/ha per year, or 2.7 t C/ha per year (Glenn et al., 1993). Areas of cultivated histosols are not provided by the Census of Agriculture, so area estimates were based on the expert opinion of numerous soil and crop specialists across Canada (G. Padbury and G. Patterson, personal communication). The total area of cultivated organic soils in Canada (for the period 1990–2003) was estimated to be 15 654 ha.

7.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

7.2.3.1 Cultivation of Mineral Soils

Given the high degree of spatial variability in SOC, there is a high degree of uncertainty associated with the CO_2 estimates provided by the Century model. Initial comparisons of Century outputs with field measurements showed that the rate of carbon gain under carbon-conserving practices predicted with the Century model was lower than that observed on the prairies, but higher than that observed in eastern Canada (Smith et al., 1997; McConkey, 1998).

Work to improve the reliability of model estimates of soil carbon change in response to no-till practices in the prairies is under way, so for this report, no further runs of the Century model were made to produce a consistent time series and enable comparability with previous estimates. Hence, the 1997–2003 CO_2 emissions and removals are projections based on the 1996 Census of Agriculture. Work currently under way to improve those estimates is described in the Planned Improvements section.

7.2.3.2 Lime Application

The major uncertainty associated with emissions due to lime application, which is expected to be low to moderate, is the annual lime consumption activity data. Thus, the overall uncertainty associated with this source of emission estimates is expected to be low to moderate.

7.2.3.3 Cultivation of Organic Soils

The uncertainty associated with emissions from this source is due to the uncertainties associated with the area estimates for the cultivated histosols and the emission factor. The uncertainty associated with the area estimate is expected to be low to moderate. The uncertainty associated with the emission factor is assumed to be moderate. Thus, the overall uncertainty associated with this source of emission estimates is expected to be moderate. The same methodology and emission factor are used for the entire time series (1990–2003).

7.2.4 QA/QC AND VERIFICATION

Being a key category, Cropland Remaining Cropland has undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2003). The activity data, methodologies, changes to methodologies, and QC checks are documented and archived in both paper and electronic form.

7.2.5 RECALCULATIONS

In previous submissions, the area of cultivated organic soils was estimated to be 29 800 ha in Canada. Following extensive consultations with federal and provincial soil and crop specialists (G. Padbury and G. Patterson, personal communication), this value was updated to 15 654 ha. Recalculations of CO_2 emissions from this source were carried out for the entire time series from 1990 to 2003. Emission estimates before and after the change were 0.07 Mt and 0.06 Mt, respectively. No other recalculations have been carried out in the Cropland Remaining Cropland category.

7.2.6 PLANNED IMPROVEMENTS

As noted at the beginning of this chapter, Canada is engaged in a multi-year effort to substantially improve its LULUCF Sector estimates. Under the direction of an inter-departmental Agriculture Working Group of the MARS–LULUCF, Canada is developing a GHG monitoring and reporting framework for agricultural lands (the National Carbon and Greenhouse Gas Accounting and Verification System) in order to meet the IPCC Good Practice Guidance (IPCC, 2003) requirements. A number of different methodologies for estimating soil carbon stock changes associated with agricultural management practices are being evaluated. For various practices, work currently under way includes a comparison of carbon factors generated by empirical studies and models such as DayCent. Estimates of areas subject to changes in practices and management are derived based on data from the Census of Agriculture series.

7.3 OTHER LULUCF CATEGORIES

The three remaining LULUCF Sector categories are Grassland, Wetlands, and Settlements. As with other LULUCF Sector categories, these are divided into lands that have remained in their categories and lands that have been converted to a new category.

7.3.1 GRASSLAND

Estimation of GHG emissions and removals from (managed) grassland remaining grassland is a new reporting requirement under the UNFCCC, brought about by the IPCC Good Practice Report for LULUCF (IPCC, 2003: Chapter 3.4, "Grassland"). Canada has not yet developed estimates in this new category. However, work is under way to address this gap within the institutional framework already described in the above Sections 7.1.6 and 7.2.6, ensuring that definitions, approaches, and methods are consistent among all managed land categories. Estimates due to land conversion to grassland are reported and considered in more detail under Section 7.4, Land Conversion.

7.3.2 WETLANDS

Wetlands include land covered or saturated by water for all or part of the year and that does not fall into the forest land, cropland, grassland, or settlements categories. New reporting requirements also arise from the IPCC Good Practice Guidance for LULUCF concerning wetlands (IPCC, 2003). The Good Practice Guidance report calls for the estimation and reporting of GHG emissions and removals from land conversion to wetlands, specifically peat extraction and flooding (IPCC, 2003: Chapter 3.5, "Wetlands"). Work is under way to address these requirements.

7.3.3 SETTLEMENTS

This land category includes all developed land, transportation and other infrastructure, and human settlements of any size. Canada includes under "Settlements Remaining Settlements" estimates of carbon sequestration in urban trees. Although the estimation procedures are very approximate, this estimate was included under the previous LUCF category "Changes in Forest and Other Biomass Stocks" and for consistency and transparency is simply reported here without modification. This component has a very minor contribution to the LULUCF Sector and a low priority for improvement.

The IPCC Good Practice Guidance report (IPCC, 2003) provides estimation procedures for reporting land conversion to settlements and attached GHG emissions or removals. Part of this requirement was already addressed in the estimation of forest and grassland conversion. Estimate derivation and associated issues are presented in Section 7.4 below, Land Conversion.

7.4 LAND CONVERSION[40]

While in theory the estimation procedures discussed in this section could be reported under Sections 7.1–7.3 above, this particular section was developed to reflect the following circumstances:

1) The methodological issues, approaches, and data sources used to derive areas undergoing conversion, as well as the sources of uncertainty, are very similar, if not identical. Grouping all these discussions into a single section enhances the transparency and simplicity of the text.
2) Most of the land conversion — or land-use change — estimates reported in this submission were developed according to the former LUCF structure, with an emphasis on the conversion of forest and grassland to other land uses; Table 7-2 illustrates the links between the two reporting structures. More time is needed to implement the new, land-based reporting structure effectively.
3) As explained in Section 7.4.6, significant efforts are under way to address methodological and data gaps in the derivation of land conversion estimates; in the meantime, and while these improvements are under preparation, minor modifications will be brought to the reporting of land conversion.

Interested readers are invited to consult Tables 5.A–5.E of the CRF, where areas, emissions, or removals are broken down according to the new structure for Lands Converted to Forest Land, Cropland, Grassland, and Settlements.

7.4.1 SOURCE CATEGORY DESCRIPTION

This section reports the estimates of CO_2 emissions and removals associated with the conversion of forests and grassland to cropland, grassland, and urban lands and the regrowth of abandoned agricultural lands into forests. Both biomass and soil carbon stocks are included in the assessment.

It is estimated that in any year in the 1990–2003 period, about half a million hectares of abandoned agricultural lands revert to forests. In contrast, on average, 71 kha of forest land are converted annually to cropland (29 kha), grassland (31 kha), or urban land (11 kha), and approximately 78 kha of grassland are converted to either cropland (63 kha) or urban land (15 kha). Carbon removals in the biomass and soils of regrowing forests (1 Mt CO_2 per year) are largely exceeded by emissions due to the conversion of 92 kha of land to cropland (16 Mt CO_2 per year), 31 kha to grassland (5 Mt CO_2 per year), and 26 kha to urban lands (6 Mt CO_2 per year).

7.4.2 METHODOLOGICAL ISSUES

In Canada, land management activities are decentralized and under the jurisdiction of provinces and territories. The predominant land uses and their associated policy drivers and governance vary greatly across the country, as do the quality, quantity, and availability of information on land management systems. Different departments in the provincial, territorial, and federal governments collect and compile land management information, but it is not reconciled in a way that would allow the consistent tracking of land transfers between different land uses at the national scale. The rapid evolution of geographic information system (GIS) technology over the last two decades enabled the development of powerful tools to record, analyze, display, and archive geospatial data, but the lack of common standards also enhanced the institutional barriers to the exchange of land resource data. Ongoing multi-departmental initiatives aim at resolving this situation, but their enabling effect will not be felt for several years.

Currently, the most reliable and consistent source of land-use information is arguably the Census of Agriculture, distributed and compiled every five years by Statistics Canada since 1956.[41] The Census of Agriculture is an inventory of the Canadian farm population and collects information on the social, economic, and land-use characteristics of these farms. In the context of this inventory, data collected on agricultural crops, pasture, and total farm areas provide the best available source of information for tracking land-use change. Methods and procedures are being developed to extract from the Census of Agriculture the most accurate and relevant information on land-use change; they are briefly described in Section A3.2 of this report. For the time being, average annual estimates are linearly interpolated from 1991–2001 decadal changes and applied to the entire inventory period (1990–2003).

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[40] For the purpose of this report, the expressions "land conversion" and "land-use change" will be used without distinction.

[41] See website: www.statcan.ca/english/agcensus2001/about.htm

Of all inventory sectors, the importance of historical data is probably greatest in assessing the emissions and removals associated with land-use change, because the effect of these activities on ecosystem carbon pools lasts for extended time periods. Methods for tracking and accounting for the fate of lands evolved rapidly over the last decades; reconciling old and current land-use change information will present an additional challenge to the already considerable task of estimating GHG emissions and removals in this sector.

7.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As in all LULUCF Sector land categories, uncertainties attached to land-use change estimates and their impact on GHG fluxes pertain to definitions, methodology, and data. The greatest source of uncertainty stems from the scarcity of quantitative information on the extent and geographical location of significant land-use changes and the types and characteristics of ecosystems encroached upon by these changes. Major assumptions are made in the derivation of estimates, such as attribution factors to the source of new cropland and pasture areas in different ecological zones, the fate of converted cropland and pasture areas, and the application of a few pre- or post-conversion carbon densities (see Section A3.2 for more details). Because the Census of Agriculture, the provincial forest inventories, and other potential regional land-use information systems do not function in a consistent and comparable manner, it is impossible at this point to accurately track land transfers between main land uses and determine, for example, the extent to which managed and non-managed forests are affected by land-use changes. Notably, there is much uncertainty on what, if any, land-use change would have contributed to a reduction in the managed forest area as compiled in Canada's Forest Inventory. Moreover, different practices in the removal of vegetation cover and topsoil, as well as mitigation and remediation activities, have a significant influence on the impact of land-use changes. At the present time, these are poorly documented, if at all, and constrain the development of more accurate estimates of GHG fluxes.

Finally, one should note that some important land conversion activities are still omitted — notably the conversion of forest land to non-urban roads, mines, hydroelectric reservoirs, and oil and gas infrastructure.

The steps taken to address these uncertainties are described below (Section 7.4.6) as planned improvements.

7.4.4 QA/QC AND VERIFICATION

Lands Converted to Cropland, to Grassland, and to Settlements are key categories in this edition of the GHG inventory. As such, they have undergone for this submission the Tier 1-level QC checks as elaborated in the framework for the QA/QC plan (see details and references in Annex 6) in a manner consistent with Good Practice Guidance (IPCC, 2003). The activity data, methodologies, changes to methodologies, and QC checks are documented and archived in both paper and electronic form.

7.4.5 RECALCULATIONS

Refined indicators on the evolution of urban built-up areas over the last four decades were made available by Statistics Canada (2005). This supported a reassessment of the average annual increase in urban built-up area for each decade. For the 1991–2001 decade, the average annual increase in urban built-up lands is 45 kha, of which 25%, or approximately 11 kha, is estimated to be deforested. This estimate differs from the previous 19 kha assessment and results in lower emission estimates associated with forest losses to urbanization from 3 Gg (2004 submission) to 1.8 Gg (this submission). This change was applied to the entire time series.

7.4.6 PLANNED IMPROVEMENTS

Addressing the current gaps in land management information has been given a high priority and is being coordinated through the Land-Use Change Working Group of the MARS–LULUCF. Ongoing work by Environment Canada, NRCan, Agriculture and Agri-Food Canada, and Statistics Canada aims to develop a land-use change information system that would support the development of the activity data required for reporting GHG emissions and removals under the UNFCCC and the Kyoto Protocol. The emphasis is on the definition of common operational land class definitions that meet the IPCC legend (IPCC, 2003); the establishment of a stratification framework that facilitates the exchange of land cover and land-use data among stakeholders; the development of land-use change matrices for pilot areas; and the creation of additional land cover and land-use data when necessary. Examples of ongoing, related work include a multi-agency partnership to develop the tools and approaches to detect, assess, and document the impact of deforestation activities in the Canadian landscape (Leckie et al., 2003); work to document urbanization in Canada over the last two decades (Guindon and Zhang, 2004); and several satellite mapping programs funded jointly by the Canadian Space Agency (R. Hélie, personal communication, 2004). These efforts are expected to significantly enhance reporting capabilities within the next five years.

In the short term, work is also under way to refine the land-use change assessment methodology from the Census of Agriculture, described in Section A3.2 of this report. Planned activities include further refinement of the spatial resolution for the time-series analysis, cross-validation of results with independent, published data sources (Jobin et al., 2003), improvement of attribution parameters, and extension of the analysis to pre-1990 Census years. Once the type, location, and extent of land conversion are known with greater certainty, the next steps will consist of documenting various land-use change practices and assessing their impact on ecosystem carbon pools.

8 WASTE (CRF SECTOR 6)

This category includes emissions from the treatment and disposal of wastes. Sources include solid waste disposal on land (landfills), wastewater treatment, and waste incineration. The categories evaluated are CH_4 emissions from solid waste disposal on land, CH_4 and N_2O emissions from wastewater treatment, and CO_2, CH_4, and N_2O emissions from waste incineration.

Much of the waste treated or disposed of is biomass or biomass based. CO_2 emissions attributable to such wastes are not included in inventory totals. In theory, there are no net emissions if the biomass is sustainably harvested. For example, CO_2 generated from aerobic decomposition of food wastes would be consumed by the next year's crop. On the other hand, CH_4 emissions from anaerobic decomposition of wastes are included in inventory totals.

If biomass is harvested at an unsustainable rate (i.e., faster than annual regrowth), net CO_2 emissions will appear as a loss of biomass stocks in the LULUCF Sector.

In 2003, the GHG emissions from the Waste Sector contributed 25 Mt to the national inventory as compared with 20 Mt for 1990, representing an increase of 27%. The emissions from this sector form 3.4% of the overall Canadian GHG emissions of 2003.

Emissions from the Solid Waste Disposal on Land subsector, which consists of the combined emissions from MSW landfills and wood waste landfills, accounted for 24 Mt or 93% of the emissions for this sector in 2003. The chief contributor to the Waste Sector remains the CH_4 released from MSW landfills, which amounted to 1 Mt in 2003. This emission value results from subtracting the total estimated CH_4 generated within the landfill by the quantity of CH_4 captured for flaring or energy recovery purposes. Approximately 23% of the CH_4 generated in Canadian MSW landfills in 2003 was captured and combusted.

The increase in the CH_4 generation rate from MSW landfills is directly dependent upon the population growth and the waste generation rate and is mitigated by the landfill gas capture rate. It is expected that as larger and more "state of the art" landfills are constructed, where gas collection systems will be required, a greater portion of landfill gas will be captured in the future, resulting in a greater reduction of emissions from this sector.

Table 8-1 summarizes the Waste Sector and subsector GHG contributions for the 1990, 2002, and 2003 inventory years.

TABLE 8-1: Waste Sector GHG Emissions Summary, Selected Years

		kt CO_2 eq	
GHG Source Category	**1990**	**2002**	**2003**
Waste TOTAL	**20 000**	**25 000**	**25 000**
a. Solid Waste Disposal on Land	19 000	23 000	24 000
b. Wastewater Handling	1 200	1 400	1 400
c. Waste Incineration	320	350	360

8.1 SOLID WASTE DISPOSAL ON LAND (CRF CATEGORY 6.A)

8.1.1 SOURCE CATEGORY DESCRIPTION

Emissions are estimated from two types of landfills in Canada:

- MSW landfills; and
- wood waste landfills.

In Canada, most, if not all, waste disposal on land occurs in municipally managed or privately owned landfills. Very few, if any, unmanaged waste disposal sites exist. Therefore, it has been assumed that all waste is disposed of in managed facilities. Residential, institutional, commercial, industrial, construction, and demolition wastes are disposed of in MSW landfills.

Wood waste landfills are privately owned and operated by forest industries, such as saw mills and pulp and paper mills. These industries use the landfills to dispose of surplus wood residue, such as sawdust, wood shavings, bark, and sludges. Some industries have shown increasing interest in waste-to-energy projects that produce steam and/or electricity by combusting these wastes. Wood waste landfills have been identified as a source of CH_4 emissions; however, there is a great deal of uncertainty in the estimates. Wood waste landfills are a minor source in comparison with MSW landfills.

The IPCC guidelines (IPCC/OECD/IEA, 1997) provide two methodologies for estimating emissions from landfills: a default method and a first-order kinetics method, also known as the Scholl Canyon model. The default method relates emissions to the quantity of waste landfilled in the previous year, whereas the Scholl Canyon model relates emissions to the waste that has been landfilled in previous years.

The composition and amount of waste landfilled in Canada have significantly changed over the past several decades, primarily as a result of population growth. For this reason, a static model such as the default method is not felt to be appropriate. Therefore, emissions from MSW landfills and wood waste landfills are estimated using the Scholl Canyon model.

The following is an explanation of both the factors that contribute to landfill gas generation and the Scholl Canyon model that was used to estimate GHG emissions from landfills.

Landfill gas, which is composed mainly of CH_4 and CO_2, is produced by the anaerobic decomposition of organic wastes. The first phase of this process typically begins after waste has been in a landfill for 10–50 days. Although the majority of CH_4 and CO_2 is generated within 20 years of landfilling, emissions can continue for 100 years or more (Levelton, 1991).

A number of important site-specific factors contribute to the generation of gases within a landfill, including the following:

- *Waste Composition*: Waste composition is probably the most important factor affecting landfill gas generation rates and quantities. The amount of landfill gas produced is dependent on the amount of organic matter landfilled. The rate at which gas is generated is dependent on the distribution and type of organic matter in the landfill.
- *Moisture Content*: Water is required for anaerobic degradation of organic matter. The amount of moisture within a landfill also significantly affects gas generation rates.
- *Temperature*: Anaerobic digestion is an exothermic process. The growth rates of bacteria tend to increase with temperature until an optimum is reached. Therefore, landfill temperatures may be higher than ambient air temperatures. The extent to which ambient air temperatures influence the temperature of the landfill and gas generation rates depends mainly on the depth of the landfill. It has been observed that landfill temperatures fluctuate with long-term ambient temperature variations (Levelton, 1991).
- *pH and Buffer Capacity*: The generation of CH_4 in landfills is greatest when neutral pH conditions exist. The activity of methanogenic bacteria is inhibited in acidic environments.
- *Availability of Nutrients*: Certain nutrients are required for anaerobic digestion. These include carbon, hydrogen, nitrogen, and phosphorus. In general, MSW contains the necessary nutrients to support the required bacterial populations.
- *Waste Density and Particle Size*: The particle size and density of the waste also influence gas generation. Decreasing the particle size increases the surface area available for degradation and therefore increases the gas production rate. The waste density, which is largely controlled by compaction of the waste as it is placed in the landfill, affects the transport of moisture and nutrients through the landfill, which also affects the gas generation rate.

8.1.2 METHODOLOGICAL ISSUES

CH_4 emissions are determined by calculating the amount of CH_4 generated from landfill waste decomposition and subtracting the CH_4 captured through landfill gas recovery systems.

CH_4 produced from the decomposition of waste in landfills is calculated using the Scholl Canyon model, which is a first-order decay model. This reflects the fact that waste degrades in landfills over many years. Landfill gas capture data were collected directly from the landfills with gas capture systems.

8.1.2.1 CH_4 Produced

The Scholl Canyon model was used to estimate emissions using the following first-order decay equation (IPCC/OECD/IEA, 1997):

Equation 8-1:

$$G_i = M_i * k * L_0 * \exp^{-(k \cdot t_i)}$$

where:

G_i = emission rate from the ith section (kt CH_4/year)
M_i = mass of refuse in the ith section (Mt)
k = CH_4 generation rate (1/year)
L_0 = CH_4 generation potential (kg CH_4/t of refuse)
t_i = age of the ith section (years)

In order to estimate CH_4 emissions from landfills, information on several of the factors described above is needed. To calculate the net emissions each year, the sum of G_i for every section of waste landfilled in past years was taken, and the captured gas was subtracted. A computerized model has been developed to estimate aggregate emissions on a regional basis in Canada.

Waste Disposed of Each Year or the Mass of Refuse (M_i)

- **MSW Landfills**

The amount of MSW landfilled in the years 1941 through to 1989 was estimated by Levelton (1991). For the years 1990 to the present, the amount of waste landfilled has been estimated based on an Environment Canada (1996) study containing solid waste data for the year 1992. Using these data, a per capita landfilling rate for each province was calculated. These rates are adjusted for the other years based on data from the National Solid Waste Inventory (CCME, 1998). The total waste disposed of each year has been determined by multiplying the per capita landfilling rate by the provincial population, as recorded by Statistics Canada (2002).

- **Wood Waste Landfills**

The amount of wood waste landfilled in the years 1970 through to 1992 has been estimated at a national level based on the Wood Residue Data Base (NRCan, 1997). The amount of wood residue landfilled in the years 1993–2003 was estimated based on information in a study of pulp and paper mill waste (MWA Consultants Paprican, 1998), a study of mill residue (SEAFOR, 1990), and an internal Canadian Pulp and Paper Association document (Reid, 1998).

Methane Generation Rate (k)

The CH_4 kinetic rate constant (k) represents the first-order rate at which CH_4 is generated after waste has been landfilled. The value of k is affected by four major factors: moisture content, availability of nutrients, pH, and temperature. The moisture content and temperature are largely determined by climatic conditions at the landfills. The k values used to estimate emissions from both types of landfills originate from a study that acknowledges limitations of the available data (Levelton, 1991). The k values are largely based on values determined by tests at various U.S. landfills. The U.S. k values are related to precipitation, assuming that the moisture content of a landfill is a direct function of the annual precipitation. Based on both the U.S. k values and precipitation data, the average annual precipitation and mean daily temperature at Canadian landfills have been calculated, and k values have been assigned to each of the provinces (Levelton, 1991).

- **MSW Landfills**

The k values used to estimate emissions from MSW landfills have been chosen from the range of k value estimates for each province (Levelton, 1991). These values are provided in Table 8-2.

- **Wood Waste Landfills**

Only one k value has been chosen to represent all of the wood waste landfills in Canada. British Columbia, Quebec, Alberta, and Ontario together landfill 93% of the wood waste in Canada (NRCan, 1997). The lowest k value given for each of these four provinces was 0.01/year (Levelton, 1991). The lowest value has been assumed to be the most appropriate, since the rate at which wood waste biodegrades is most likely slower than the rate for other types of organic MSW (such as food and paper waste). This is due to the limited quantity of nutrients in wood waste that are required by the active bacteria (Tchobanoglous et al., 1993).

TABLE 8-2: **MSW Landfill k Value Estimates for Each Province/Territory**

Provincial/Territorial k Value Estimates (1/year)											
NL	PE	NS	NB	QC	ON	MB	SK	AB	BC	NT[1]	YT
0.0110	0.0110	0.0110	0.0110	0.0240	0.0240	0.0060	0.0060	0.0060	0.0280	0.0030	0.0030

Note:
[1] NT includes NU.

Methane Generation Potential (L_0)

- **MSW Landfills**

The values of theoretical and measured L_0 range from 4.4 to 194 kg CH_4/t of waste (Pelt et al., 1998). For the years 1941 through to 1989, a value for L_0 of 165 kg CH_4/t of waste (as suggested by the U.S. EPA) has been used (Levelton, 1991). The following equation was used to calculate an L_0 value for the years since 1990 (ORTECH Corporation, 1994):

Equation 8-2:

$$L_0 = (M_c \cdot F_b \cdot S)/2$$

where:

M_c = tonnes of carbon per tonne of waste landfilled

F_b = biodegradable fraction

S = stoichiometric factor

The carbon content (M_c) in the waste on a dry basis is determined as a percentage of the waste disposed of and is divided into two categories: biodegradable carbon and refractory carbon. Biodegradable carbon is the carbon contained in degradable items such as food, paper, and wood wastes. Refractory carbon is the carbon in items such as plastic, which degrades very slowly and is therefore unavailable for GHG generation.

The biodegradable fraction (F_b) has been determined by dividing the biodegradable carbon by the total carbon. The stoichiometric factor for CH_4 in Equation 8-2 above is 16/12, the ratio of the molecular mass of CH_4 to that of carbon. The product of the three variables is divided by two, since it is assumed that 50% of the gas produced will be CH_4 and the other 50% will be CO_2 (Pelt et al., 1998).

Based on these considerations, an L_0 of 117 kg CH_4/t of waste was calculated. As waste disposal practices in Canada change, the L_0 value will be adjusted accordingly.

- **Wood Waste Landfills**

Equation 8-2 generated an L_0 value of 118 kg CH_4/t of wood waste, which was used to estimate emissions from wood waste landfills by the Scholl Canyon model. The data required to calculate this value originate from several sources (SEAFOR, 1990; NRCan, 1997; MWA Consultants Paprican, 1998; Reid, 1998).

Captured Landfill Gas

Some of the CH_4 that is generated in MSW landfills is captured and combusted. Through combustion, this landfill CH_4 converts into CO_2, reducing the emissions of CH_4. In order to calculate the net CH_4 emissions from landfills, the captured quantity is subtracted from the estimate generated by the Scholl Canyon model.

Data on the amount of landfill gas captured are collected directly from individual landfill operators biennially by Environment Canada's National Office of Pollution Prevention (Environment Canada, 2003a). Since the landfill gas capture data are collected every odd year, for the purposes of the National GHG Inventory, it is assumed that these data are identical for the subsequent even inventory year.

8.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The following discussion on uncertainty for the categories within this sector is based upon the results as reported in *Quantitative Assessment of Uncertainty in Canada's National GHG Inventory Estimates for 2001* (ICF, 2004). This Tier 2 evaluation of uncertainty employed values from the 2001 inventory year (2003 submission); however, it is assumed to be generally relevant to the present inventory year, since no changes were made to the methodology, emission factors, or source of activity data used in emission estimation within this sector.

The CH_4 emissions from this key category include the CH_4 emissions from the MSW landfills and from the wood waste landfills. The level uncertainty associated with the CH_4 emissions from the combined subsectors was estimated to be in the range of -35% to 40%, which closely resembles the uncertainty range of -40% to 35% estimated in this study for the CH_4 emissions from the MSW landfills. The level uncertainty range provided by the ICF (2004) study is only slightly larger than the ±30% span estimated with a 90% confidence level by a previous study that used a Tier 1 approach based upon 1990 data (McCann, 1994). However, it should be noted that the ICF study's uncertainty range is quoted for a 95% confidence interval, which would typically be larger than the range quoted for a 90% confidence interval.

The MSW landfills contributed to over 90% of the total CH_4 emissions from this key category in 2001

(Environment Canada, 2003b). The uncertainty estimates for the CH_4 emissions from the MSW landfills seem to have been largely influenced by the uncertainty in the inventory values for the CH_4 generation potentials (L_0) for 1941–1989 and for 1990–2001 and the CH_4 generation rate constant (k). Here, the uncertainty ranges for k and L_0 were based upon an estimate from one expert elicitation. A simplified model of the Scholl Canyon method was used for the Monte Carlo simulation, which may have had a bearing on the accuracy of the uncertainty values. An error was introduced in the calculation of the MSW landfill CH_4 emission uncertainty by the use of the year 2000 inventory value for the total CH_4 captured in Canada, resulting in an uncertainty range of 20% to 24%. The actual uncertainty for this activity data entry should have been ±2%.

Although the uncertainty range estimated in this study for the wood waste landfills was significantly higher (i.e., -60% to 190%) than that for the MSW landfills, its contribution to the uncertainty in the key category was much lower due to its relatively low contribution of emissions (i.e., less than 10%) (Environment Canada, 2003b). The uncertainty estimate for wood waste landfills seems to have been largely influenced by the CH_4 generation rate, carbon content of the waste landfilled, and the biodegradable fraction of the waste, where the uncertainties were assumed by ICF Consultants (ICF, 2004), based upon IPCC guidelines (IPCC/OECD/IEA, 1997) and/or IPCC Good Practice Guidance (IPCC, 2000) wherever possible.

The estimates are calculated in a consistent manner over time.

8.1.4 QA/QC AND VERIFICATION

A Tier 1 QC review was conducted for this key category. No significant anomalies were identified.

8.1.5 RECALCULATIONS

Two recalculations were made to the emission estimates from the municipal landfills. The first was conducted due to population updates for the 1990–2002 period based upon data from the 2003 *Annual Demographic Statistics* published by Statistics Canada (2003). The revised Statistics Canada figures gave slightly lower population values over this period. The percent difference in the national population figures from the 2002 to the 2003 inventories varied from -0.002% to -0.3% over the 1990–2002 interval.

The second recalculation pertained to the landfill gas capture data for the inventory years 1997–2002 that were updated to reflect the corrections made to the 1997, 1999, and 2001 editions of the *Inventory of Landfill Gas Recovery and Utilization in Canada* (Environment Canada, 2003a). The correction entailed changing the density of the CH_4 portion of the landfill gas used for *Inventory of Landfill Gas Recovery and Utilization in Canada* calculations to reflect standard temperature and pressure (STP). For this purpose, STP refers to a temperature of 25°C and pressure of 101.325 kPa (1 atmosphere). Previously, the density was calculated using a temperature of 0°C and a pressure of 101.325 kPa. Based on a temperature of 0°C and a pressure of 101.325 kPa, the density of CH_4 is 0.717 kg/m^3, while at STP, the density of CH_4 is 0.6557 kg/m^3. To maintain consistency, these changes have been made to the previous inventories. The consequence of the CH_4 density correction was a reduction of the mass of CH_4 captured over this time period.

Finally, there was a significant increase in the CH_4 emission estimate for the year 2002 in the 2003 inventory report from that of the previous year due to a correction in the data entry for the model.

8.1.6 PLANNED IMPROVEMENTS

Three main studies are planned for 2005 to improve the accuracy and completeness of this subsector. The first proposed study will consist of a compilation of MSW composition data from across Canada and will include a review of the CH_4 generation potential calculation methodology based upon these data as well as an evaluation of province-specific CH_4 generation rate constants used in the Scholl Canyon model. The second study will focus on improving the wood waste landfill activity data. The third will be a multi-year study, commencing in 2005, comprising a critical review of the present Scholl Canyon model employed for the estimation of the CH_4 generated from MSW landfills and an inventory of landfills in Canada in preparation for a possible Tier 3 estimation approach.

Due to the limited number of GHG inventory years covered by Environment Canada's *Inventory of Landfill Gas Recovery and Utilization in Canada*, it was decided to postpone the allocation to the Energy Sector of the portion of captured landfill gas utilized for energy recovery until consistency concerns were addressed, to allow for recalculations from the base year to the current inventory. Therefore, for this and prior inventories, all the captured landfill gas was assumed to have been flared.

8.2 WASTEWATER HANDLING (CRF CATEGORY 6.B)

8.2.1 SOURCE CATEGORY DESCRIPTION

Emissions from municipal wastewater treatment were estimated. Municipal wastewater can be aerobically or anaerobically treated. When wastewater is treated anaerobically, CH_4 is produced; however, it is typical that systems with anaerobic digestion in Canada contain and flare the produced CH_4. CH_4 emissions from aerobic systems are negligible. Both types of systems generate N_2O through the nitrification and denitrification of sewage nitrogen (IPCC/OECD/IEA, 1997).

CO_2 is also generated by both types of treatment. However, as discussed above, CO_2 emissions originating from the decomposition of food are not to be included with the national estimates, in accordance with IPCC guidelines (IPCC/OECD/IEA, 1997).

The emission estimation methodology for wastewater handling is divided into two areas: CH_4 from anaerobic wastewater treatment and N_2O from human sewage.

Emissions from treatment of industrial wastewater were not calculated due to a lack of data on the industries that treat their own wastewater.

8.2.2 METHODOLOGICAL ISSUES

8.2.2.1 CH_4 Emissions

The IPCC default method was not used, because the required data were not available. A method developed for Environment Canada (ORTECH Corporation, 1994) was used to calculate an emission factor. Based on the amount of organic matter generated per person in Canada and the conversion of organic matter to CH_4, it was estimated that 4.015 kg CH_4/person per year could potentially be emitted from anaerobically treated wastewater.

An emission factor for each province was calculated by multiplying this potential emission rate by the fraction of anaerobically treated wastewater in each province (Environment Canada, 1981).

Emissions are calculated by multiplying the emission factors by the population of the respective province (Statistics Canada, 2002).

8.2.2.2 N_2O Emissions

The N_2O emissions were calculated using the IPCC default method (IPCC/OECD/IEA, 1997). This method estimates emissions based on the amount of nitrogen in sewage and the assumption that 0.01 kg N_2O-N/kg sewage N will be generated.

Estimates of the amount of nitrogen in sewage were based on the following two assumptions: protein is 16% nitrogen; and Canadian protein consumption is 40.15 kg/person per year. This resulted in an emission factor of 0.101 kg N_2O/person per year.

Emissions were calculated by multiplying the emission factor by the population of the respective provinces (Statistics Canada, 2002).

8.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The following discussion on uncertainty for the categories within this sector is based upon the results as reported in *Quantitative Assessment of Uncertainty in Canada's National GHG Inventory Estimates for 2001* (ICF, 2004). This Tier 2 evaluation of uncertainty employed values from the 2001 inventory year (2003 submission); however, it is assumed to be generally relevant to the present inventory year, since no changes were made to the methodology, emission factors, or source of activity data used in emission estimation within this sector.

The overall level uncertainty associated with the wastewater treatment subsector was estimated to be in the range of -40% to 55%. The level uncertainty range provided by the ICF (2004) study is less than the ±60% span estimated with a 90% confidence level by a previous study that used a Tier 1 approach based on 1990 data (McCann, 1994). This is an improvement to the uncertainty as assessed for this category, since the uncertainty range quoted by ICF (2004) for a 95% confidence interval should typically show a larger value than that quoted for a 90% confidence interval. In the 2001 inventory, the trend uncertainty associated with the total GHG emissions (comprising CH_4 and N_2O) from the wastewater treatment systems was estimated to be in the range of about 12% to 13%. The extrapolation of trend uncertainty in 2001 to the current 2003 inventory should be made with caution, as the trend uncertainty is more sensitive than level uncertainty to the changes in the inventory estimate values for the more recent years. The CH_4 emissions accounted for about 85% of the total emissions from this subsector category.

Since the method and data sources have remained unchanged over the time series, the estimates for this category are consistent over time.

8.2.4 QA/QC AND VERIFICATION

A formal Tier 1 QC was conducted for this category for both N_2O (key) and CH_4 estimates. No significant anomalies were identified.

8.2.5 RECALCULATIONS

Recalculations were made to the CH_4 and N_2O values for the years 1990–2002 based upon the updated population data from the 2003 *Annual Demographic Statistics* published by Statistics Canada (2003). The revisions to the population data are described in Section 8.1.5. The revised population numbers were only slightly less than the previous inventory estimates, resulting in a very small decrease of the CH_4 and N_2O emission estimates over the 1990–2002 period.

8.2.6 PLANNED IMPROVEMENTS

Canada is planning to update the wastewater emission data based upon the results from a study that would include an inventory of wastewater treatment plants in Canada, quantification of GHG releases, and an estimation of GHG emission factors.

8.3 WASTE INCINERATION (CRF CATEGORY 6.C)

8.3.1 SOURCE CATEGORY DESCRIPTION

Emissions from both MSW and sewage sludge incineration are included in the inventory. Several municipalities in Canada utilize incinerators to reduce the quantity of MSW sent to landfills and to reduce the amount of sewage sludge requiring land application.

GHG emissions from incinerators vary depending on factors such as the amount of waste incinerated, the composition of the waste, the carbon content of the non-biomass waste, and the facilities' operating conditions.

8.3.1.1 MSW Incineration

A combustion chamber of a typical mass-burn MSW incinerator is composed of a grate system on which waste is burned and is either water-walled (if the energy is recovered) or refractory-lined (if it is not). GHGs that are emitted from MSW incinerators may include CO_2, CH_4, and N_2O.

As per IPCC guidelines (IPCC/OECD/IEA, 1997), CO_2 emissions from biomass waste combustion are not included in this section of the inventory. The only CO_2 emissions included in this section are from fossil fuel-based carbon waste, such as plastics and rubber.

CH_4 emissions from MSW incineration are assumed to be negligible and are not calculated due to a lack of underlying emission research.

8.3.1.2 Sewage Sludge Incineration

Two different types of sewage sludge incinerators are used in Canada: multiple hearth and fluidized bed. In both types of incinerators, the sewage sludge is partially de-watered prior to incineration. The de-watering is typically done in a centrifuge or using a filter press. Currently, municipalities in Ontario and Quebec operate sewage sludge incinerators.

Only CH_4 emissions are estimated from sewage sludge incineration, due to a lack of underlying emission research.

8.3.2 METHODOLOGICAL ISSUES

The emission estimation methodology depends on waste type and gas emitted.

8.3.2.1 CO_2 Emissions

The IPCC guidelines (IPCC/OECD/IEA, 1997) do not specify a method to calculate CO_2 emissions from the incineration of fossil fuel-based waste (such as plastics and rubber). Therefore, the following three-step method was developed:

1) *Calculating the Amount of Waste Incinerated*: The amount of waste incinerated each year is based on an Environment Canada (1996) study, which contains detailed provincial incineration data for the year 1992. To estimate the amount of MSW incinerated in other years, 1992 data were extrapolated based on population growth figures (Statistics Canada, 2002).

2) *Developing Emission Factors*: Provincial CO_2 emission factors are based on the assumption that carbon contained in waste undergoes complete oxidation to CO_2. The amount of fossil fuel-based carbon available in the waste incinerated has been determined using typical percent weight carbon constants (Tchobanoglous et al., 1993). The amount of carbon per tonne of waste is estimated and converted to tonnes of CO_2 per tonne of waste by multiplying by the ratio of the molecular mass of CO_2 to that of carbon.

3) *Calculating CO_2 Emissions*: Emissions were calculated on a provincial level by multiplying the amount of waste incinerated by the appropriate emission factors.

8.3.2.2 N_2O and CH_4 Emissions

Emissions of N_2O from MSW incineration were estimated using the IPCC default method (IPCC/OECD/IEA, 1997). An average factor was calculated assuming that the IPCC five stokers facility factors were most representative. To estimate emissions, the calculated factor was multiplied by the amount of waste incinerated by each province.

Emissions are dependent on the amount of dried solids incinerated. To calculate the CH_4 emissions, the amount of dry solids incinerated is multiplied by an appropriate emission factor. Estimates of the amount of dried solids in the sewage sludge incinerated in the years 1990–1992 are based on a study completed in 1994 (W. Fettes, personal communication, 1994). Data for the years 1993–1996 were acquired through telephone surveys of facilities that incinerate sewage sludge.

Emissions of CH_4 are estimated based on emission factors obtained from the U.S. EPA publication *Compilation of Air Pollutant Emission Factors* (EPA, 1995). The emission factors are 1.6 t/kt of total dried solids for fluidized bed sewage incinerators and 3.2 t/kt of dried solids for multiple hearth incinerators, both equipped with venture scrubbers. Only CH_4 has been considered in calculating emissions from sewage sludge incineration.

8.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The following discussion on uncertainty for the categories within this sector is based upon the results as reported in *Quantitative Assessment of Uncertainty in Canada's National GHG Inventory Estimates for 2001* (ICF, 2004). This Tier 2 evaluation of uncertainty employed values from the 2001 inventory year (2003 submission); however, it is assumed to be generally relevant to the present inventory year, since no changes were made to the methodology, emission factors, or source of activity data used in emission estimation within this sector.

The overall level uncertainty associated with the waste incineration source category was estimated to be in the range of -12% to 65%. For 2001 inventory estimates, the overall trend uncertainty associated with the total GHG emissions (comprising CO_2, CH_4, and N_2O) from incineration of wastes (comprising MSW and sewage sludge) was estimated to be in the range of about 10% to 11%. The inventory trend was estimated at 10%. The extrapolation of trend uncertainty in 2001 to the current 2003 inventory should be made with caution, as the trend uncertainty is more sensitive than the level uncertainty to the changes in the inventory estimate values for the more recent years. CH_4 accounted for over 80% of the total GHG emissions from this source category.

Due to a lack of data, emissions from sewage sludge incineration are assumed to be constant since 1996.

8.3.4 QA/QC AND VERIFICATION

A formal Tier 1 QC was conducted for this source for CO_2 (key), CH_4, and N_2O estimates. No significant anomalies were identified.

8.3.5 RECALCULATIONS

The CO_2 emissions from fossil fuel-based waste and N_2O emissions were recalculated for the years 1990–2002 to account for the population data update based upon the 2003 *Annual Demographic Statistics* published by Statistics Canada (2003). The revisions to the population data are described in Section 8.1.5.

The revised population numbers were only slightly less than the previous inventory estimates, resulting in a very small decrease of the CO_2, CH_4, and N_2O emission estimates over the 1990–2002 period.

8.3.6 PLANNED IMPROVEMENTS

An analysis of the municipal incineration activity data is planned. The study proposal includes a historical compilation of the activity data from 1990 to 2004, a current inventory of all Canadian MSW incinerators, waste composition, annual throughput for each unit, and estimated GHG emission factors.

9 RECALCULATIONS AND IMPROVEMENTS

This chapter presents a summary of the recalculations performed for this submission and a summary of the planned improvements to the overall inventory. The reader will find in Chapters 3 through 8 the category-specific details of the recalculations, along with a description by GHG category of planned improvements to methodologies and data.

9.1 EXPLANATIONS AND JUSTIFICATIONS FOR RECALCULATIONS

Each year, Environment Canada reviews and, if necessary, revises and recalculates the emissions and removals estimates for all years in the inventory. This work is carried out as part of continuous improvement efforts to integrate refined data or methods, incorporate new information or additional sources and sinks, implement any new guidance, and correct errors and omissions.

In this submission, some recalculations were made due to structural changes in the UNFCCC reporting categories in the Agriculture and LULUCF sectors. Due to changes in the reporting guidelines, CO_2 emissions from agricultural soils and non-CO_2 emissions from forest fires are now reported with the LULUCF Sector (previously known as LUCF), leading to recalculations for both the Agriculture and LULUCF sectors.

Other recalculations originate from changes in methodologies. Examples include emissions from aluminium production as well as a new method to allow a better distinction between domestic and international aviation emissions. Finally, a number of recalculations were made, in particular in the Energy, Waste, Industrial Processes, and LULUCF sectors, as a result of regular updates to the underlying activity data or the availability of new emission source information. For example, the inclusion of electrical equipment as a new source of SF_6 emissions entailed some recalculations for the Industrial Processes Sector.

This section provides a summary of the major recalculations performed in each sector, followed by a description of the impacts on GHG levels and trends.

9.1.1 ENERGY

Fuel combustion emission estimates were revised for 2002, since Statistics Canada, the source of the fuel consumption data, revised its recent fuel-use data. This affected the estimates for the Energy Industries, Manufacturing and Construction, and Other industrial subsectors. Pulp, Paper and Print CH_4 and N_2O estimates were also recalculated for the entire time series, as they were previously incorrectly reported under the residential subcategory. Estimates for coal emissions (Energy Industries) were recalculated for 1990–2002 after revised emission factors were obtained based on the 2000 fossil fuel emission factors study.

With respect to the Transport sector, a major recalculation was performed for the entire time series for domestic aviation estimates due to the incorporation of flight activity data within the fuel allocation methodology. As a result, domestic air transport fuel consumption data and associated emissions were revised downwards (and, conversely, emissions from international aviation [bunkers] were revised upwards).

In addition, the update of the original spreadsheet-based MGEM to the relational database (MS Access) MGEM 05 has resulted in minor shifts between On-Road and Off-Road fuel allocations and the associated emissions throughout the entire time series. MGEM 05 also has improved data handling capacity, which accommodates updated vehicle population data sets for 2001 and 2002, leading to further recalculations for the 2001 and 2002 transport estimates.

Finally, for the Fugitive oil and gas emissions, a correction to the spreadsheet links induced recalculations for the 2000–2002 time series for light and medium oil production.

9.1.2 INDUSTRIAL PROCESSES

Recalculations were completed for several categories in the Industrial Processes Sector for this submission.

Under Mineral Production and Use, recalculations were made to both the lime production and limestone use 2002 CO_2 emission estimates, since new or updated 2002 activity data became available. Soda ash use estimates were recalculated for the 1990–2002 time series to take into account newly acquired activity data for 1994 and 1995.

Under Metal Production, the 2002 CO_2 emission estimates for iron and steel production were recalculated due to the acquisition of updated 2002 consumption data for metallurgical coke. In addition, PFC estimates for aluminium production over 1990–2002 were significantly revised downwards further to the introduction of a new methodology to incorporate estimates obtained from the AAC.

Estimates of HFC emissions for the 1996–2002 time period were significantly revised upwards due to the use of more accurate activity data for both stock and consumption of HFCs. Recalculations in the Industrial Processes Sector also reflect the fact that two new sources have been included — namely, SF_6 emissions from magnesium casting and from the use of SF_6 in electrical equipment in utilities.

9.1.3 SOLVENT AND OTHER PRODUCT USE

In this sector, the revision of demographic statistics led to recalculations for 1990–2002 estimates of N_2O emissions from medical applications and from the use of N_2O as a propellant. These updates had a negligible impact.

9.1.4 AGRICULTURE

The key change for the 2005 submission is the move of the soil CO_2 emissions and removals from the Agriculture Sector to the LULUCF Sector, which affected quite significantly the total agricultural sectoral GHG level and trends (see Sections 9.2 and 9.3). In addition, as detailed in Chapter 6 on the Agriculture Sector, many recalculations have been carried out in this submission due to methodological upgrades and updates and revisions in animal populations.

The adoption of Tier 2 methods for enteric emissions from cattle and for CH_4 emissions from manure management induced recalculations in those two categories for the complete time series. Furthermore, the addition of buffaloes to the animal population accounts, coupled with the revision to the goat population for 1990–1995 and the complete revision to the poultry population accounts, implied recalculations anywhere animal populations are primary activity data (enteric, manure management, manure used as fertilizer, manure on pasture, and direct and indirect soil N_2O emissions). In addition, the manure CH_4 category now includes goats and horses. Recalculations of the N_2O emission estimates from manure and from direct and indirect soil categories were also triggered by the use of the updated distribution of the various manure management system types in Canada obtained from a recent survey. Finally, the revised area of histosols in Canada and the adoption of the IPCC Good Practice Guidance (IPCC, 2000) emission factor for those soils led to the complete recalculation of the associated N_2O emissions. Details can be found in the category-specific sections of Chapter 6 (Agriculture Sector).

9.1.5 LAND USE, LAND-USE CHANGE AND FORESTRY

The radical change in the structure of this sector due to the implementation of Good Practice Guidance for LULUCF (IPCC, 2003) can be construed as a recalculation in itself for the overall sector, in particular because of the inclusion of CO_2 emissions/removals from cropland soils (previously reported in the Agriculture Sector). In addition, a number of recalculations were made in this submission, involving a methodological change and activity data updates.

Concerning the managed forest, the first recalculation reflects the implementation of a refined method to estimate areas burned annually by wildfires in managed forests. The new approach is based on a spatial overlay of the boundaries of the forest inventory spatial units with geographical location of large forest fires. Recalculations in this category also involved the incorporation of certain data from CanFI 2001 that were not available in the 2004 submission, resulting in a change in the total area of managed forests.

As a consequence, smaller estimates of area burned in the managed forests combined with updated forest inventory data caused an apparent increase in the area of managed forest actively sequestering carbon throughout the reporting period, leading to a revised greater sink from the managed forests.

Other recalculations in the LULUCF Sector were due to the incorporation of refined indicators on the evolution of urban built-up areas (leading to revised estimates of forest losses to urbanization), the reporting of urban tree growth under the LULUCF Settlements category (previously reported under 5A: Changes in Forest and Other Woody Biomass Stocks), and the revised cultivated histosols area for CO_2 emissions from croplands.

9.1.6 WASTE

Updates to the population statistics generated by Statistics Canada led to the recalculation of most of the categories in this sector, with a minimal effect. CH_4 landfill emission estimates were recalculated for 1990–2002. CH_4 and N_2O emissions from wastewater treatment were also recalculated, as well as CO_2 and N_2O emissions from waste incineration. For solid waste disposal, revisions to the landfill gas capture data for 1997–2002 were also responsible for the recalculations in that category for those years. Finally, the previous estimate of CH_4 emissions from landfills for 2002 was revised after running the model another time.

9.2 IMPLICATIONS FOR EMISSION LEVELS

Table 9-1 provides a summary, both by sector and for national GHG totals, of the quantitative effects of recalculations. For information on how LULUCF categories are treated in the table, the reader should refer to the notes.

Overall, changes in emission levels were fairly significant due mainly to recalculations undertaken in the Energy Sector (aviation), Industrial Processes, and Agriculture sectors; and the change in reporting category for forest fire emissions. Total GHG emissions (excluding the LULUCF Sector) were overall revised downwards. Revisions vary between about -4 Mt (-0.6%) for 2001 and about -29 Mt (-4.5%) for 1994. The variability of changes is mainly due to the fact that non-CO_2 emissions from forest fires were removed from the national totals, as explained above. These emissions have a high interannual variability and reach a peak for the years 1994, 1995, and 1998.

For the Energy Sector, recalculations resulted in a decrease in reported emissions by between 3 Mt (-0.7%) for 1991 and 9 Mt (-1.6%) for 2002.

For the Industrial Processes Sector, recalculations resulted in an increase in emissions of about 1 Mt for 1990 (or a 1.8% increase for this sector). For 2000, 2001, and 2002, the increases amounted to about 3.5 Mt (7.5%), 3 Mt (6.1%), and 2 Mt (3.2%), respectively. Emission levels for 1993–1996 decreased by between 0.2% and 2%.

For the Solvent and Other Product Use Sector, recalculations resulted in minimal changes.

For the Agriculture Sector, overall recalculations resulted in changes between -11.9% in 1990 (about -7 Mt) and +1.0% in 2002 (about +1 Mt). These recalculations mainly resulted from the change in reporting category, moving soil CO_2 emissions and removals from the Agriculture Sector to the LULUCF Sector. These estimates amounted to 7.4 Mt in 1990 and -0.7 Mt in 2002.

For the Waste Sector, recalculations resulted in 0% change for 1990 and 2.3% and 4.9% increases in emissions for 2001 and 2002, respectively.

For the LULUCF Sector (not included in national totals), the effect of recalculations on the level of estimates is very significant for two reasons, as explained above: incorporation of CO_2 emissions/removals from agricultural soils (previously included in the Agriculture Sector) and inclusion of non-CO_2 forest fire emissions (previously a separate subcategory of LUCF). In addition, recalculations due to changes in methodologies predominate in years where large forest fires had been incorrectly located in the managed forests — namely, in 1994, 1995, and 1998 (see Table A3-21 in Annex 3). As a result, the sector as a whole was erroneously believed to be a source for the years 1994 and 1998. This correction brings about large relative differences for those three years.

TABLE 9-1: Recalculations Summary

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Mt CO_2 eq													
National Total[1]														
Previous	**609**	**603**	**618**	**624**	**659**	**675**	**675**	**682**	**700**	**705**	**725**	**716**	**731**	**N/A**
Current	596	589	606	608	630	646	663	675	682	696	720	712	719	740
% Change	-2.1	-2.3	-1.9	-2.5	-4.5	-4.3	-1.8	-1.1	-2.6	-1.3	-0.7	-0.6	-1.7	–
Energy														
Previous	473	464	482	482	498	513	528	539	549	564	589	582	592	N/A
Current	469	461	478	478	494	508	522	534	543	558	582	576	583	600
% Change	-0.8	-0.7	-0.8	-0.8	-0.8	-0.9	-1.1	-1.1	-1.1	-1.2	-1.2	-1.0	-1.6	–
Industrial Processes														
Previous	53	55	53	55	58	57	59	57	54	50	49	48	49	N/A
Current	54	55	54	54	57	57	58	58	55	53	52	51	51	52
% Change	1.8	0.9	0.2	-1.8	-2.0	-0.2	-1.5	0.8	3.0	5.7	7.5	6.1	3.2	–
Solvent														
Previous	0.42	0.42	0.43	0.43	0.44	0.44	0.45	0.45	0.46	0.46	0.46	0.47	0.47	N/A
Current	0.42	0.42	0.43	0.43	0.44	0.44	0.45	0.45	0.45	0.46	0.46	0.47	0.47	0.48
% Change	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.3	-0.2	-0.2	-0.2	–
Agriculture[2]														
Previous	59	58	58	58	61	61	62	61	61	61	61	60	59	N/A
Current	52	52	53	54	57	58	60	60	60	61	61	60	59	62
% Change	-11.9	-11.1	-9.4	-7.6	-6.8	-4.8	-2.8	-1.9	-1.2	-0.6	0.0	0.7	1.0	–
Waste														
Previous	20	21	21	22	22	22	22	23	23	24	24	24	24	N/A
Current	20	21	21	22	22	22	22	23	24	24	25	24	25	25
% Change	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.2	0.3	0.3	2.3	4.9	–
LULUCF[3]														
Previous	-154	-131	-135	-85	99	115	-85	-106	32	-49	-74	-79	-21	N/A
Current	-154	-133	-140	-110	-110	8	-89	-102	-60	-68	-85	-89	-33	-44
% Change	-0.2	1.6	3.0	30	-211	-93	4.7	-3.8	-288	38	15	14	57	–

Notes:

1 National totals: Previous estimates include non-CO_2 emissions from forest fires (LUCF Sector). Current estimates exclude the entire new LULUCF Sector (including all forest fire emissions).

2 Agriculture: Previous estimates include CO_2 from agricultural soils; current estimates exclude it (as per revised UNFCCC guidelines).

3 LULUCF: Previous estimates correspond to the previous LUCF Sector with CO_2 only. Current estimates include CO_2 from agricultural soils and non-CO_2 from forest fires (as per the revised UNFCCC guidelines).

N/A = Not Applicable

9.3 IMPLICATIONS FOR EMISSION TRENDS

Overall, the recalculations of the total GHG estimates (excluding LULUCF) had a relatively small effect on the long-term trend (1990–2002), amounting to less than 1%. The 1990–2002 increase previously reported was 20%; it is now almost 21%. This is mainly due to the change in reporting structure for CO_2 from agricultural soils and non-CO_2 emissions from fires.

For the Energy Sector, the emission trend over 1990–2002 is now +24%, compared with +25% previously reported.

For the Industrial Processes Sector, recalculations had a smoothing effect on the sectoral trends. The increase in emissions between 1990 and 1996 is now +7% (compared with +11% reported in 2004). The decrease over 1996–2002 amounts to 13% (compared with 17% previously). Over the 1990–2002 period, emissions from this sector decreased by 6% (previously 8%).

For the Solvent and Other Product Use Sector, recalculations had no impact on the trends.

For the Agriculture Sector, moving soil CO_2 emissions and removals from the Agriculture Sector to the LULUCF Sector significantly changed the trends. The increase in GHGs for the sector over 1990–2002 is now about 14% compared with the 1% change previously reported when CO_2 emissions and removals from agricultural soils were included. The other recalculations had very little impact on the trends.

In the Waste Sector, the increase in emissions over 1990–2002 is now 24%, compared with 18% previously reported. Due to the recalculations, 2002 emissions from this sector are now more than 2% higher than in 2001 (previously, they were quasi-equal).

In the LULUCF Sector (excluded from national totals), both short- and long-term trends are not particularly meaningful, given that emissions are driven by the forest fire emissions, which are extremely variable from one year to the next. However, one can note that the impact of recalculations in this sector is more apparent in later years of the entire time series, since estimates of the early 1990s largely rely on 1990 forest inventory data, while subsequent ones are derived from calculations on the evolution of the stocked forest area. Hence, errors created throughout the reporting period by mislocation of fires tend to cumulate, and corrections produce larger changes in recent-year estimates. Nevertheless, the sector as a whole retains the important interannual variability resulting from large fluctuations in the severity of the fire season, with an additional random effect due to the location of fires with respect to the managed forests.

9.4 PLANNED IMPROVEMENTS

Improvement activities and work plans are developed on a continuous basis to further refine and increase the transparency, completeness, accuracy, consistency, and comparability of the Canadian GHG inventory. The following is a discussion of current improvement activities and plans based on recommendations provided by the external review process, the UNFCCC expert review teams' annual reports, and inventory sector experts. Improvement plans are developed and prioritized based on key category contributions and resource availability. Some improvements span several years.

9.4.1 QUALITY ASSURANCE/ QUALITY CONTROL

A framework for a QA/QC plan for the national GHG inventory was developed in 2004 (SNC Lavallin, 2004) in order to meet the IPCC Good Practice Guidance and UNFCCC requirements. Based on this framework, the design and implementation of the first steps of the QA/QC plan are currently proceeding (see Annex 6 for a description of activities implemented for the 2005 submission). To enable the full development and implementation of the program, including the archiving and documentation requirements, the GHG Division is in the process of staffing a QA/QC coordinator. For each sector and category, with an initial focus on key categories, QA/QC activity books will be expanded upon and Tier 2 QC and QA plans will be developed, including audits and review plans, as well as verification activities, expanding upon and formalizing current activities. A critical short-term priority consists of the consolidation and expansion of the documentation of the inventory process and of the QA/QC activities, in addition to the development of a GHG archiving system up to standards. All of these activities will ultimately be integrated within a continuous and dynamic quality management cycle for the national inventory.

9.4.2 UNCERTAINTIES

Building on the uncertainty study with Tier 2 analysis completed in 2004 (ICF, 2004), further work is under way to enhance and refine the uncertainty assessment of the GHG inventory. These improvements include a sensitivity analysis to evaluate the sensitivity of the overall inventory to the uncertainty of input parameters and the development of an overall inventory trend uncertainty. As well, uncertainty assessments will be done for categories not included in the 2004 study and/or for which changes to methods and data have been made or are being implemented (e.g., Tier 2 method for enteric fermentation and CH_4 from manure management, LULUCF managed forests and croplands). A mid-term goal is to build internal capacity for uncertainty analysis through the development of an uncertainty quantification system, with linkages to the emissions/removals system, to allow updates to uncertainty estimates as activities, data, and methods change.

9.4.3 KEY CATEGORIES

Future improvement plans also include the development of an IPCC Good Practice Guidance Tier 2 key category analysis model based on the Tier 2 uncertainty analysis.

9.4.4 DATA MANAGEMENT SYSTEM

The GHG Division has initiated a planning process to develop a data management system for the entire GHG inventory. A first step in 2005 is to define and assess the business requirements, including the option of a multi-user relational inventory database. A second phase of what is anticipated to be a multi-year project will consist of designing, testing, and implementing the system.

9.4.5 ENERGY SECTOR

As far as energy industries are concerned, CAPP and Environment Canada have initiated the development of a recalculation model based on the results of the upstream oil and gas study completed in late 2004. A study has been initiated on the Canadian bitumen industry and is expected to be completed in 2005, with the aim of refining the current estimation method for the unconventional bitumen industry. In addition, the recent study of GHG emissions that was completed for the petroleum refining industry is currently being assessed with respect to its potential use for improving the quality and accuracy of the inventory as well as for assisting in the development of a venting and flaring estimation model. Finally, improvements are also planned for the consumption of solid fuels category, involving the collection of carbon and energy content information on coal.

With respect to manufacturing and construction categories, Environment Canada and Statistics Canada are working jointly to improve the quality of the national energy balance and to further disaggregate fuel-use information.

9.4.5.1 Transportation

The transport model (MGEM 05), recently upgraded, will continuously evolve to exploit the power of the relational database to accommodate an increasing number of higher-resolution data being made available through partnerships and reporting. Future improvements will concentrate on obtaining better activity data, in particular higher-resolution vehicle population profiles, improved Vkmt estimates, and improved disaggregation of marine activity data to better distinguish domestic and international emissions.

9.4.6 INDUSTRIAL PROCESSES SECTOR

Improvements for mineral products include investigations into the potential inclusion of limestone use by the pulp and paper industry and a search for new sources of recent soda ash use data. For ammonia production, efforts will be made to determine the quantity of CO_2 stored in exported fertilizer. For nitric acid, future work will assess the possibility of incorporating an N_2O destruction factor and abatement system factor into the emission estimation methodology. Furthermore, the potential for including SF_6 emissions from aluminium production in the inventory will be investigated. For SF_6 emissions from magnesium casters, the results of the remaining questionnaires filled in by industry will be incorporated into future estimates. Other efforts will focus on acquiring more recent consumption data for halocarbons, on SF_6 in the utility industry for 2004 through the CEA, and on disaggregation of the CO_2 emissions included in the Other and Undifferentiated category, utilizing industry-reported non-energy fuel use and application-specific emission factors.

9.4.7 AGRICULTURE SECTOR

For this sector, the development of Tier 2 uncertainty estimates for enteric fermentation and CH_4 from manure Tier 2 methods is planned in the short term. The potential use of country-specific Tier 2 emission factors for N_2O emissions from soils (fertilizer, manure application) and the derivation of national direct N_2O emission estimates through modelling are currently being investigated in conjunction with Agriculture and Agri-Food Canada. Another investigation also includes the potential use of specific harvest indices and nitrogen content data to improve estimates of N_2O emissions from crop residue decomposition.

9.4.8 LAND USE, LAND-USE CHANGE AND FORESTRY SECTOR

Canada is engaged in a multi-year and multi-agency effort to substantially improve its estimates for the LULUCF Sector in order to implement and meet the IPCC Good Practice Guidance (IPCC, 2003), including the quantification of uncertainties. Canada has adopted an incremental approach to the implementation of its MARS for LULUCF. Therefore, each inventory submission incorporates improvements as they become available, rather than all at once. Overall, as explained below, efforts are prioritized towards the harmonization across land uses and towards the top key categories — namely, managed forests, croplands, and deforestation.

To this effect, work is well under way to develop a framework for estimating GHG emissions and removals for the category "Forest Land Remaining Forest Land," based on a spatially defined managed forest and an updated CBM of the Canadian forest sector, including the integration of the now-excluded carbon pools. Similarly, for croplands and grasslands, a land-based system is currently being developed to estimate carbon stock changes from certain land management soil landscape situations, according to Good Practice Guidance.

Regarding the challenging new land-based reporting structure from Good Practice Guidance, efforts are coordinated towards a consistent land representation through consistent definitions, approaches, and methods across all managed land categories. Canada is developing a land-use change information system whose design and implementation will span several years. Besides the refinement of the land-use change assessment methodology from the Census of Agriculture described in Annex 6, tools are being developed to detect, assess, and document the impact of deforestation activities in the Canadian landscape. Work is also under way to address GHG emissions and removals from land conversion to wetlands — namely, peat extraction and flooding.

9.4.9 WASTE SECTOR

Improvements to the emission estimates from landfills encompass three main studies in 2005 — namely, the harmonization of the collection of the MSW composition data with provinces and municipalities, collection of improved wood waste landfill activity data, and a multi-year review of the current Scholl Canyon model and improved inventory of landfills. Furthermore, it is planned that a portion of the captured landfill gas will eventually be allocated to the Energy Sector once better data are obtained. In addition, work is planned to update the wastewater emission data as well as to analyze the municipal incineration activity data.

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ANNEX 1: KEY CATEGORIES

A1.1 KEY CATEGORIES — METHODOLOGY

Both the IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000) and the IPCC *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003) recommend as good practice the identification of key categories of emissions and removals. The intent is to help inventory agencies prioritize their efforts to improve overall estimates. A key category is defined as "one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both" (IPCC, 2000).

This annex describes the key category analysis conducted for Canada's 2003 inventory, according to IPCC approaches.

Good practice first requires that inventories be disaggregated into categories from which key sources and sinks may be identified. Source and sink categories are defined according to the following guidelines:

- IPCC categories should be used with emissions specified in CO_2 equivalent units according to standard GWPs.
- A category should be identified for *each* gas emitted by the source, since the methods, emission factors, and related uncertainties differ for each gas.
- Source categories that use the same emission factors based on common assumptions should be aggregated before analysis.

The Canadian analysis of categories for key sources and sinks proceeds according to the Tier 1 Good Practice Guidance approaches of IPCC (2000, 2003). Using the Tier 1 method, key categories are first identified by *quantitative* methods using a predetermined cumulative emissions threshold. Second, Tier 1 key categories are determined by *qualitative* approaches. A more comprehensive Tier 2 approach is recommended if uncertainty estimates are available. In this approach, the results of Tier 1 are multiplied by the relative uncertainty of the source and sink category. Since uncertainty estimates are not available for the LULUCF Sector, Tier 1 methods have been used for key category determination.

The quantitative approach identifies key categories from two perspectives. The first analyzes the emission contribution that each category makes to the national total (with and without LULUCF). The second perspective analyzes the trend of emission contributions from each category to identify where the greatest absolute changes (either increases or reductions) have taken place over a given time (with and without LULUCF categories). The percent contributions to both levels and trends in emissions are calculated and sorted from greatest to least. A cumulative total is calculated for both approaches. IPCC has determined that a cumulative contribution threshold of 95% for both level and trend assessments is a reasonable approximation of 90% uncertainty for the Tier 1 method of determining key categories (IPCC, 2000). The 95% cumulative contribution threshold has been used in this analysis to define an upper boundary for key category identification. Therefore, when source and/or sink contributions are sorted in decreasing order of importance, those that contribute to 95% of the cumulative total are considered quantitatively to be key.

Level contribution of each source is calculated according to Equation A1-1, which follows IPCC (2000), while Equation A1-2 is used to calculate the level contribution from both sources and sinks following IPCC (2003):

Equation A1-1 for source category level assessment:

$$L_{x,t} = E_{x,t}/E_t$$

where:

$L_{x,t}$ = the level assessment for source x in year t

$E_{x,t}$ = the emission (CO_2 eq) estimate of source category x in year t

E_t = the total inventory estimate (CO_2 eq) in year t

Equation A1-2 for source/sink category level assessment:

$$L_{x,t}^{*} = E_{x,t}^{*}/E_t^{*}$$

where:

$L_{x,t}^{*}$ = level assessment for source or sink x in year t. The asterisk (*) indicates that contributions from all categories (including LULUCF categories) are entered as absolute values.

$E_{x,t}^{*}$ = $| E_{x,t} |$: absolute value of emission or removal estimate of source or sink category x in year t.

E_t^{*} = $\sum_x | E_t |$: total contribution, which is the sum of the absolute values of emissions and removals in year t. The asterisk (*) indicates that contributions from all categories (including LULUCF categories) are entered as absolute values.

Trend contribution of each source is calculated according to Equation A1-3, which follows IPCC (2000), while Equation A1-4 is use to calculate the trend contribution from both sources and sinks following IPCC (2003):

Equation A1-3 for source category trend assessment:

$$T_{x,t} = L_{x,t} \ast | \{[(E_{x,t} - E_{x,0})/E_{x,t}] - [(E_t - E_0) / E_t]\} |$$

where:

$T_{x,t}$ = the contribution of the source category trend to the overall inventory trend (i.e., the trend assessment); the contribution is always recorded as an absolute value.

$L_{x,t}$ = the level assessment for source x in year t (derived in Equation A1-1).

$E_{x,t}$ and $E_{x,0}$ = the emission estimates of source category x in years t and 0, respectively.

E_t and E_0 = the total inventory estimates in years t and 0, respectively.

Equation A1-4 for source/sink category trend assessment:

$$T_{x,t} = E_{x,t}^{*}/E_t \ast |\{[(E_{x,t} - E_{x,0})/E_{x,t}] - [(E_t - E_0)/E_t]\}|$$

where:

$T_{x,t}$ = trend assessment, which is the contribution of the source or sink category trend to the overall inventory trend. The trend assessment is always recorded as an absolute value, i.e., a negative value is always recorded as the equivalent positive value.

$E_{x,t}^{*}$ = $|E_{x,t}|$: absolute value of emission or removal estimate of source or sink category x in year t.

$E_{x,t}$ and $E_{x,0}$ = real values of estimates of source or sink category x in years t and 0, respectively.

E_t and E_0 = $\sum_x E_{x,t}$ and $\sum_x E_{x,0}$ total inventory estimates in years t and 0, respectively. E_t and E_0 differ from E_t^{*} and E_0^{*} in Equation A1-2 in that the removals are not entered as absolute values.

The qualitative approach strengthens the foregoing quantitative analysis by considering more subjective criteria to determine if a category should be listed as key. In most cases, the application of these criteria identifies categories identical to those prioritized by the quantitative analysis. However, additional categories identified as key may be added to the primary list. IPCC (2000) identifies four significant criteria for qualitative analysis. They are as follows:

1) *Mitigation techniques and technologies*: Identify those sources where emissions are being reduced significantly through the use of mitigation techniques or technologies.

2) *High expected emissions growth*: Identify sources with significant growth forecast.

3) *High uncertainty*: Identify most uncertain sources as key to help improve the accuracy of the inventory.

4) *Unexpectedly low or high emissions*: Identify calculation errors and discrepancies by doing order-of-magnitude checks.

This analysis uses three main sources of information to help define qualitative criteria. These published information sources provide valuable insight into qualitative key category assessment:

1) *Canada's First National Climate Change Business Plan* (NCCS, 2000a), *Government of Canada Action Plan 2000 on Climate Change* (Government of Canada, 2000), and *Project Green — Moving Forward on Climate Change, A Plan for Honouring Our Kyoto Commitment* (Government of Canada, 2005), outlining significant mitigation measures under way and planned in a range of sectors.
2) Forecasts of GHG emissions from source categories for a Business-as-Usual (NRCan, 1999) and a Kyoto scenario (NCCS, 2000b).
3) *Quantitative Assessment of Uncertainty in Canada's National GHG Inventory Estimates for 2001* (ICF, 2004).

The overall purpose of identifying key categories is the institution of best practices in GHG inventory development. The appropriate aggregation of categories is crucial to reflect not only actual sources and sinks but also identical estimation procedures. Thus, while the UNFCCC CRF categories provide a basis for identifying sources and sinks, some aggregation of these sources and sinks can occur when using the same emission factors based on common estimation assumptions. In this analysis, major categories such as fuel combustion, fugitive emissions, industrial processes, agriculture, and waste are in keeping with the CRF. Within these major categories, the aggregation of subcategories occurs when estimates are made based on common assumptions about emission factors and on common activity data. For example, within the fuel combustion category, emissions from residential, commercial, and agriculture subsectors are combined.

In developing source and sink categories, it is also necessary to consider each GHG separately, since estimating methods, emission factors, and related uncertainties differ for each gas. Accordingly, source and sink categories are given for each major GHG — CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6 — where that gas is a contributor to the national inventory.

A complete listing of all source and sink categories for the 2003 inventory is shown in Table A1-1.

TABLE A1-1: Source Category Analysis Summary, 2003 Inventory

Source Table	IPCC Categories	Direct GHG	Key Source Category (Yes/No)	If Yes, Criteria for Identification
1-A-1-a	Fuel Combustion – Public Electricity and Heat Production	CO_2	Yes	Level, Trend, and Quality
1-A-1-a	Fuel Combustion – Public Electricity and Heat Production	CH_4	–	–
1-A-1-a	Fuel Combustion – Public Electricity and Heat Production	N_2O	–	–
1-A-1-b	Fuel Combustion – Petroleum Refining	CO_2	Yes	Level, Trend, and Quality
1-A-1-b	Fuel Combustion – Petroleum Refining	CH_4	–	–
1-A-1-b	Fuel Combustion – Petroleum Refining	N_2O	–	–
1-A-1-c	Fuel Combustion – Manufacture of Solid Fuels and Other Energy Industries	CO_2	Yes	Level, Trend, and Quality
1-A-1-c	Fuel Combustion – Manufacture of Solid Fuels and Other Energy Industries	CH_4	–	–
1-A-1-c	Fuel Combustion – Manufacture of Solid Fuels and Other Energy Industries	N_2O	–	–
1-A-2	Fuel Combustion – Manufacturing Industries and Construction	CO_2	Yes	Level and Trend
1-A-2	Fuel Combustion – Manufacturing Industries and Construction	CH_4	–	–
1-A-2	Fuel Combustion – Manufacturing Industries and Construction	N_2O	–	–
1-A-3-a	Fuel Combustion – Civil Aviation	CO_2	Yes	Level, Trend, and Quality
1-A-3-a	Fuel Combustion – Civil Aviation	CH_4	Yes	Quality
1-A-3-a	Fuel Combustion – Civil Aviation	N_2O	Yes	Quality
1-A-3-b	Fuel Combustion – Road Transportation	CO_2	Yes	Level, Trend, and Quality
1-A-3-b	Fuel Combustion – Road Transportation	CH_4	–	–
1-A-3-b	Fuel Combustion – Road Transportation	N_2O	Yes	Level and Quality
1-A-3-c	Fuel Combustion – Railways	CO_2	Yes	Level and Trend
1-A-3-c	Fuel Combustion – Railways	CH_4	–	–
1-A-3-c	Fuel Combustion – Railways	N_2O	Yes	Quality
1-A-3-d	Fuel Combustion – Navigation	CO_2	Yes	Level
1-A-3-d	Fuel Combustion – Navigation	CH_4	–	–
1-A-3-d	Fuel Combustion – Navigation	N_2O	Yes	Quality
1-A-3-e	Fuel Combustion – Other Transport (Off-Road)	CO_2	Yes	Level, Trend, and Quality
1-A-3-e	Fuel Combustion – Other Transport (Off-Road)	CH_4	Yes	Quality
1-A-3-e	Fuel Combustion – Other Transport (Off-Road)	N_2O	Yes	Quality
1-A-3-e	Fuel Combustion – Pipeline Transport	CO_2	Yes	Level
1-A-3-e	Fuel Combustion – Pipeline Transport	CH_4	–	–
1-A-3-e	Fuel Combustion – Pipeline Transport	N_2O	–	–
1-A-4	Fuel Combustion – Other Sectors	CO_2	Yes	Level and Trend
1-A-4	Fuel Combustion – Other Sectors	CH_4	–	–
1-A-4	Fuel Combustion – Other Sectors	N_2O	–	–
1-B-1-a	Fugitive Emissions – Coal Mining	CH_4	Yes	Trend
1-B-2-(a+b)	Fugitive Emissions – Oil and Natural Gas	CO_2	–	–
1-B-2-(a+b)	Fugitive Emissions – Oil and Natural Gas	CH_4	Yes	Level, Trend, and Quality
1-B-2-c	Fugitive Emissions – Oil and Natural Gas – Venting and Flaring	CO_2	Yes	Level
1-B-2-c	Fugitive Emissions – Oil and Natural Gas – Venting and Flaring	CH_4	Yes	Quality
2-A-1	Industrial Processes – Cement Production	CO_2	Yes	Level
2-A-2	Industrial Processes – Lime Production	CO_2	–	–
2-A-3	Industrial Processes – Limestone and Dolomite Use	CO_2	–	–
2-A-4	Industrial Processes – Soda Ash Production and Use	CO_2	–	–
2-B-1	Industrial Processes – Ammonia Production	CO_2	Yes	Level
2-B-2	Industrial Processes – Nitric Acid Production	N_2O	–	–
2-B-3	Industrial Processes – Adipic Acid Production	N_2O	Yes	Trend and Quality
2-C-1	Industrial Processes – Iron and Steel Production	CO_2	Yes	Level and Trend
2-C-3	Industrial Processes – Aluminium Production	CO_2	Yes	Trend
2-C-3	Industrial Processes – Aluminium Production	PFCs	Yes	Trend
2-C-4-2	Industrial Processes – Magnesium Production	SF_6	Yes	Trend
2-C-5	Industrial Processes – Magnesium Casting	SF_6	–	–
2-F	Industrial Processes – Consumption of Halocarbons	HFCs	Yes	Trend
2-F	Industrial Processes – Consumption of Halocarbons	PFCs	–	–
2-F-8	Industrial Processes – Consumption of SF_6 for Electrical Equipment	SF_6	–	–
2-G	Industrial Processes – Other (Undifferentiated Processes)	CO_2	Yes	Level
3-D	Solvent and Other Product Use	N_2O	–	–
4-A	Agriculture – Enteric Fermentation	CH_4	Yes	Level and Trend
4-B	Agriculture – Manure Management	CH_4	–	–
4-B	Agriculture – Manure Management	N_2O	–	–
4-D	Agriculture – Direct Agricultural Soils	N_2O	Yes	Level, Trend and Quality
4-D	Agriculture – Indirect Agricultural Soils	N_2O	Yes	Level and Quality
5-A.1	LULUCF – Forest Land Remaining Forest Land	CO_2	Yes	Level and Trend
5-A.1	LULUCF – Forest Land Remaining Forest Land	CH_4	–	–
5-A.1	LULUCF – Forest Land Remaining Forest Land	N_2O	–	–
5-A.2	LULUCF – Land Converted to Forest Land	CO_2	–	–
5-B.1	LULUCF – Cropland Remaining Cropland	CO_2	Yes	Trend and Quality
5-B.2	LULUCF – Land Converted to Cropland	CO_2	Yes	Level and Trend
5-C.2	LULUCF – Land Converted to Grassland	CO_2	Yes	Level and Trend
5-E.1	LULUCF – Settlements Remaining Settlements	CO_2	–	–
5-E.2	LULUCF – Land Converted to Settlements	CO_2	Yes	Level and Trend
6-A	Waste – Solid Waste Disposal on Land	CH_4	Yes	Level, Trend, and Quality
6-B	Waste – Wastewater Handling	CH_4	–	–
6-B	Waste – Wastewater Handling	N_2O	Yes	Quality
6-C	Waste – Waste Incineration	CO_2	Yes	Quality
6-C	Waste – Waste Incineration	CH_4	–	–
6-C	Waste – Waste Incineration	N_2O	–	–

A1.2 KEY CATEGORY TABLES

A1.2.1 LEVEL ASSESSMENT WITHOUT LULUCF

Table A1-2 shows key categories indicated from level assessment without LULUCF, and Figure A1-1 shows the contribution of key categories to the level assessment.

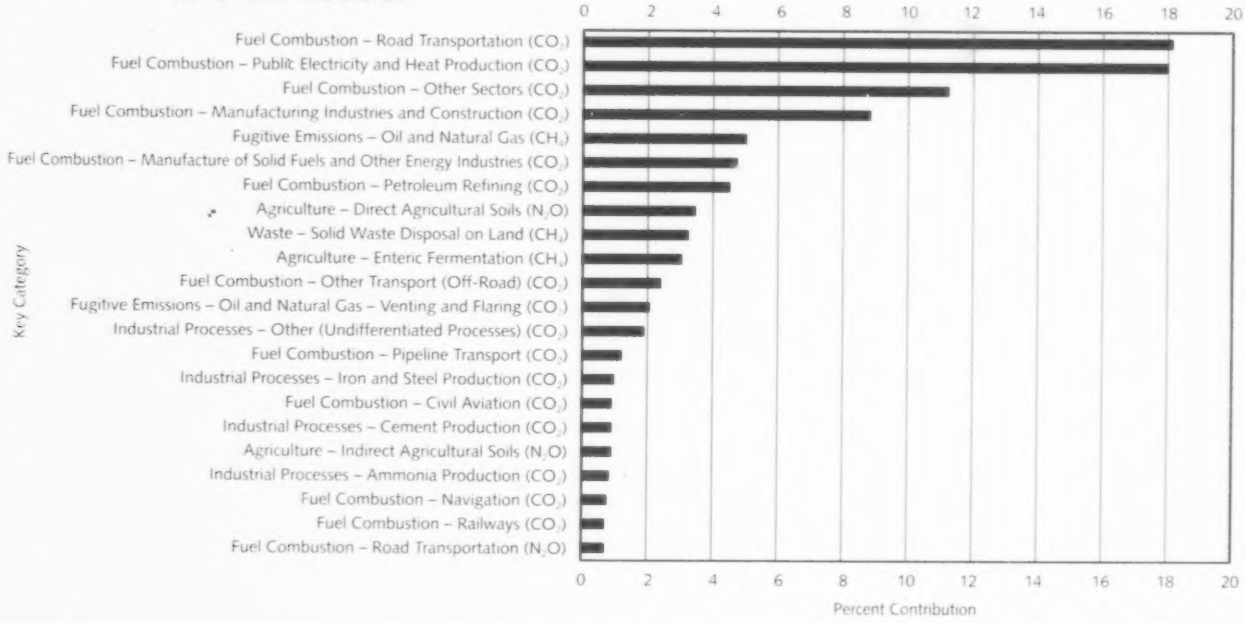
TABLE A1-2: **2003 Key Categories by Level Assessment[1] without LULUCF**

Source Table	IPCC Categories	Direct GHG	1990 (Base Year)	2003 (Current Year)	Level Assessment	Cumulative Total
			kt CO_2 eq	*kt CO_2 eq*	%	%
1-A-3-b	Fuel Combustion – Road Transportation	CO_2	102 878	134 557	18	18
1-A-1-a	Fuel Combustion – Public Electricity and Heat Production	CO_2	94 745	133 379	18	36
1-A-4	Fuel Combustion – Other Sectors	CO_2	69 415	83 802	11	48
1-A-2	Fuel Combustion – Manufacturing Industries and Construction	CO_2	62 368	65 495	8.8	56
1-B-2-(a+b)	Fugitive Emissions – Oil and Natural Gas	CH_4	25 685	37 084	5.0	61
1-A-1-c	Fuel Combustion – Manufacture of Solid Fuels and Other Energy Industries	CO_2	23 555	34 842	4.7	66
1-A-1-b	Fuel Combustion – Petroleum Refining	CO_2	25 977	33 675	4.5	71
4-D	Agriculture – Direct Agricultural Soils	N_2O	21 758	25 365	3.4	74
6-A	Waste – Solid Waste Disposal on Land	CH_4	18 530	23 702	3.2	77
4-A	Agriculture – Enteric Fermentation	CH_4	18 682	22 410	3.0	80
1-A-3-e	Fuel Combustion – Other Transport (Off-Road)	CO_2	15 086	17 648	2.4	83
1-B-2-c	Fugitive Emissions – Oil and Natural Gas – Venting and Flaring	CO_2	9 787	15 167	2.0	85
2-G	Industrial Processes – Other (Undifferentiated Processes)	CO_2	9 218	13 715	1.9	87
1-A-3-e	Fuel Combustion – Pipeline Transport	CO_2	6 705	8 846	1.2	88
2-C-1	Industrial Processes – Iron and Steel Production	CO_2	7 058	7 041	1.0	89
1-A-3-a	Fuel Combustion – Civil Aviation	CO_2	6 216	7 001	0.9	90
2-A-1	Industrial Processes – Cement Production	CO_2	5 583	6 815	0.9	91
4-D	Agriculture – Indirect Agricultural Soils	N_2O	5 105	6 550	0.9	91
2-B-1	Industrial Processes – Ammonia Production	CO_2	5 008	6 169	0.8	92
1-A-3-d	Fuel Combustion – Navigation	CO_2	4 733	5 834	0.8	93
1-A-3-c	Fuel Combustion – Railways	CO_2	6 315	5 262	0.7	94
1-A-3-b	Fuel Combustion – Road Transportation	N_2O	3 647	5 132	0.7	94

Note:

[1] IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Chapter 7, Tier 1 Analysis - Level Assessment - Sorted by % Level Assessment.

FIGURE A1-1: **2003 Contributions of Key Categories to Level Assessment without LULUCF**



A1.2.2 LEVEL ASSESSMENT WITH LULUCF

Table A1-3 shows key categories indicated from level assessment with LULUCF, and Figure A1-2 shows the contribution of key categories to the level assessment.

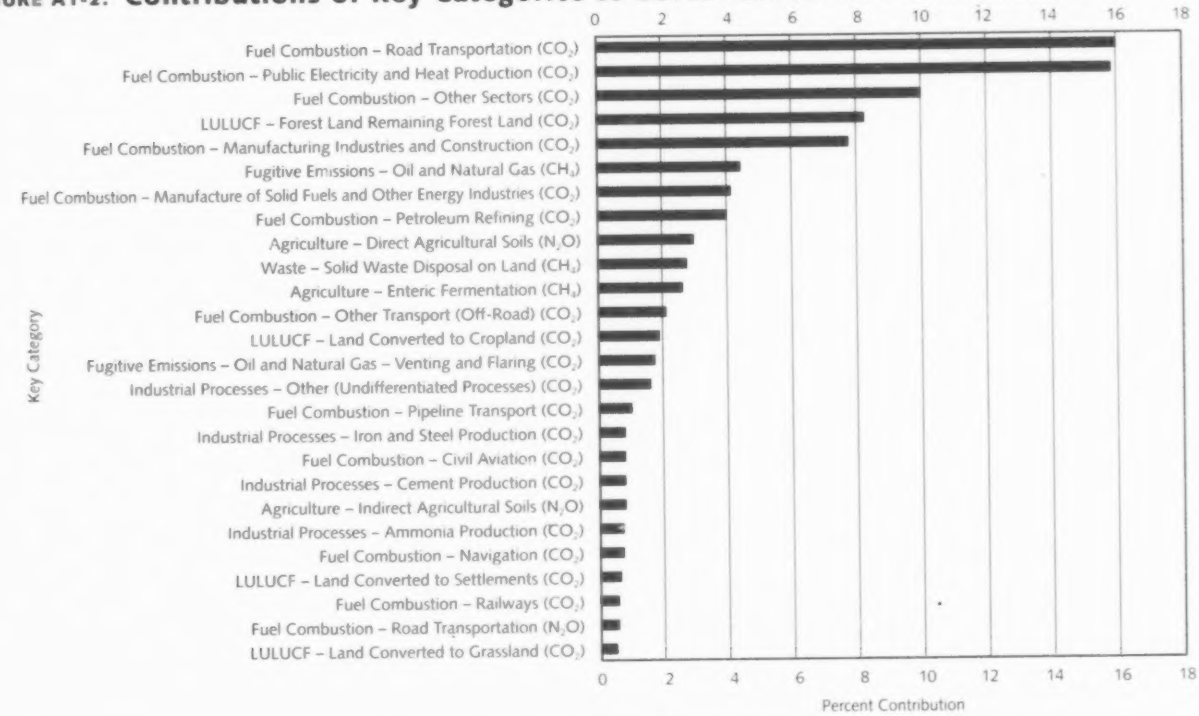
TABLE A1-3: 2003 Key Categories by Level Assessment[1] including LULUCF

Source Table	IPCC Categories	Direct GHG	1990 (Base Year) kt CO_2 eq	2003 (Current Year) kt CO_2 eq	Level Assessment %	Cumulative Total %
1-A-3-b	Fuel Combustion – Road Transportation	CO_2	102 878	134 557	16	16
1-A-1-a	Fuel Combustion – Public Electricity and Heat Production	CO_2	94 745	133 379	16	32
1-A-4	Fuel Combustion – Other Sectors	CO_2	69 415	83 802	10	42
5-A-1	LULUCF – Forest Land Remaining Forest Land	CO_2	-187 838	-69 578	8.3	50
1-A-2	Fuel Combustion – Manufacturing Industries and Construction	CO_2	62 368	65 495	7.8	58
1-B-2-(a+b)	Fugitive Emissions – Oil and Natural Gas	CH_4	25 685	37 084	4.4	62
1-A-1-c	Fuel Combustion – Manufacture of Solid Fuels and Other Energy Industries	CO_2	23 555	34 842	4.1	66
1-A-1-b	Fuel Combustion – Petroleum Refining	CO_2	25 977	33 675	4.0	70
4-D	Agriculture – Direct Agricultural Soils	N_2O	21 758	25 365	3.0	73
6-A	Waste – Solid Waste Disposal on Land	CH_4	18 530	23 702	2.8	76
4-A	Agriculture – Enteric Fermentation	CH_4	18 682	22 410	2.7	79
1-A-3-e	Fuel Combustion – Other Transport (Off-Road)	CO_2	15 086	17 648	2.1	81
5-B-2	LULUCF – Land Converted to Cropland	CO_2	15 961	15 961	1.9	83
1-B-2-c	Fugitive Emissions – Oil and Natural Gas – Venting and Flaring	CO_2	9 787	15 167	1.8	85
2-G	Industrial Processes – Other (Undifferentiated Processes)	CO_2	9 218	13 715	1.6	86
1-A-3-e	Fuel Combustion – Pipeline Transport	CO_2	6 705	8 846	1.1	87
2-C-1	Industrial Processes – Iron and Steel Production	CO_2	7 058	7 041	0.8	88
1-A-3-a	Fuel Combustion – Civil Aviation	CO_2	6 216	7 001	0.8	89
2-A-1	Industrial Processes – Cement Production	CO_2	5 583	6 815	0.8	90
4-D	Agriculture – Indirect Agricultural Soils	N_2O	5 105	6 550	0.8	91
2-B-1	Industrial Processes – Ammonia Production	CO_2	5 008	6 169	0.7	91
1-A-3-d	Fuel Combustion – Navigation	CO_2	4 733	5 834	0.7	92
5-E.2	LULUCF – Land Converted to Settlements	CO_2	5 667	5 667	0.7	93
1-A-3-c	Fuel Combustion – Railways	CO_2	6 315	5 262	0.6	93
1-A-3-b	Fuel Combustion – Road Transportation	N_2O	3 647	5 132	0.6	94
5-C.2	LULUCF – Land Converted to Grassland	CO_2	4 755	4 755	0.6	95

Note:

1 IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Chapter 7, Tier 1 Analysis - Level Assessment - Sorted by % Level Assessment.

FIGURE A1-2: Contributions of Key Categories to Level Assessment with LULUCF



A1.2.3 TREND ASSESSMENT WITHOUT LULUCF

Table A1-4 shows key categories indicated from trend assessment without LULUCF, and Figure A1-3 shows the contribution of key categories to the trend assessment.

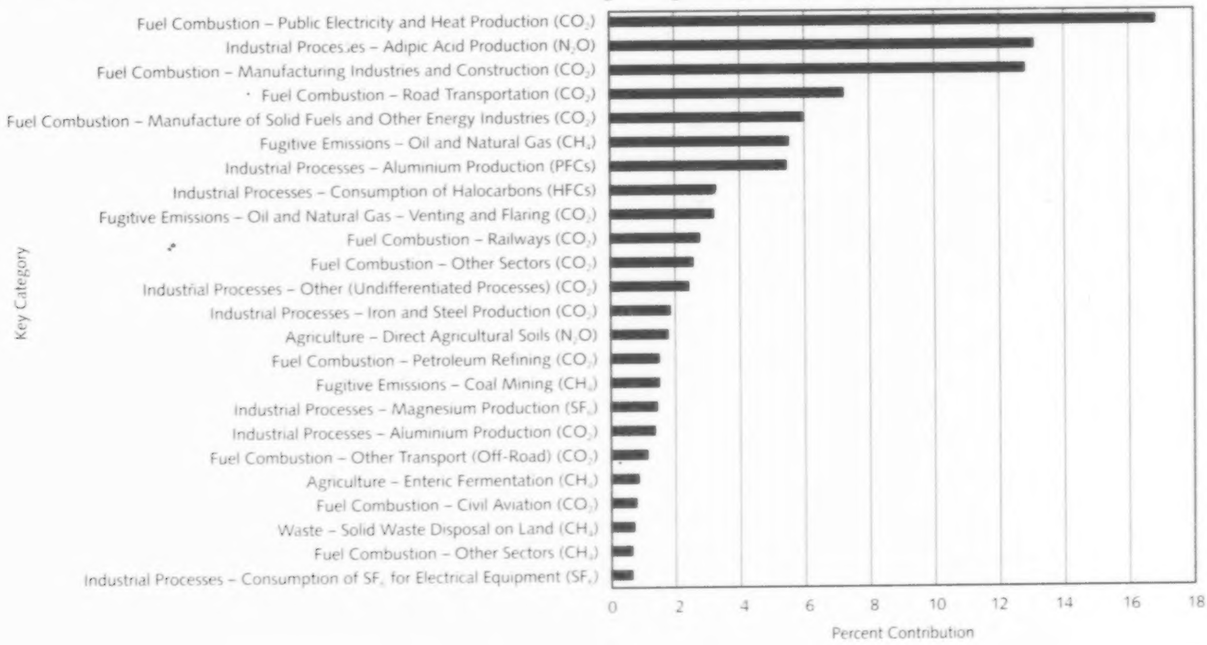
TABLE A1-4: 2003 Key Categories by Trend Assessment[1] without LULUCF

Source Table	IPCC Categories	Direct GHG	1990 (Base Year)	2003 (Current Year)	Trend Assessment	Contribution to Trend	Cumulative Total
			kt CO_2 eq	kt CO_2 eq		%	%
1-A-1-a	Fuel Combustion – Public Electricity and Heat Production	CO_2	94 745	133 379	0.017	17	17
2-B-3	Industrial Processes – Adipic Acid Production	N_2O	10 718	1 085	0.013	13	30
1-A-2	Fuel Combustion – Manufacturing Industries and Construction	CO_2	62 368	65 495	0.013	13	42
1-A-3-b	Fuel Combustion – Road Transportation	CO_2	102 878	134 557	0.007	7.2	50
1-A-1-c	Fuel Combustion – Manufacture of Solid Fuels and Other Energy Industries	CO_2	23 555	34 842	0.006	5.9	56
1-B-2-(a+b)	Fugitive Emissions – Oil and Natural Gas	CH_4	25 685	37 084	0.006	5.5	61
2-C-3	Industrial Processes – Aluminium Production	PFCs	6 297	2 741	0.006	5.4	66
2-F	Industrial Processes – Consumption of Halocarbons	HFCs	0	3 090	0.003	3.3	70
1-B-2-c	Fugitive Emissions – Oil and Natural Gas – Venting and Flaring	CO_2	9 787	15 167	0.003	3.2	73
1-A-3-c	Fuel Combustion – Railways	CO_2	6 315	5 262	0.003	2.7	76
1-A-4	Fuel Combustion – Other Sectors	CO_2	69 415	83 802	0.003	2.6	78
2-G	Industrial Processes – Other (Undifferentiated Processes)	CO_2	9 218	13 715	0.002	2.4	81
2-C-1	Industrial Processes – Iron and Steel Production	CO_2	7 058	7 041	0.002	1.8	83
4-D	Agriculture – Direct Agricultural Soils	N_2O	21 758	25 365	0.002	1.8	84
1-A-1-b	Fuel Combustion – Petroleum Refining	CO_2	25 977	33 675	0.002	1.5	86
1-B-1-a	Fugitive Emissions – Coal Mining	CH_4	1 914	990	0.002	1.5	87
2-C-4-2	Industrial Processes – Magnesium Production	SF_6	2 870	2 232	0.001	1.4	89
2-C-3	Industrial Processes – Aluminium Production	CO_2	2 636	4 577	0.001	1.4	90
1-A-3-e	Fuel Combustion – Other Transport (Off-Road)	CO_2	15 086	17 648	0.001	1.2	91
4-A	Agriculture – Enteric Fermentation	CH_4	18 682	22 410	0.001	0.8	92
1-A-3-a	Fuel Combustion – Civil Aviation	CO_2	6 216	7 001	0.001	0.8	93
6-A	Waste – Solid Waste Disposal on Land	CH_4	18 530	23 702	0.001	0.7	94
1-A-4	Fuel Combustion – Other Sectors	CH_4	2 117	1 984	0.001	0.7	94
2-F-8	Industrial Processes – Consumption of SF_6 for Electrical Equipment	SF_6	1 796	1 594	0.001	0.7	95

Note:

[1] IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Chapter 7, Tier 1 Analysis - Trend Assessment - Sorted by % Trend Assessment.

FIGURE A1-3: Contributions of Key Categories to Trend Assessment without LULUCF



A1.2.4 TREND ASSESSMENT WITH LULUCF

Table A1-5 shows key categories indicated from trend assessment with LULUCF, and Figure A1-4 shows the contribution of key categories to the trend assessment.

TABLE A1-5: 2003 Key Categories by Trend Assessment[1] including LULUCF

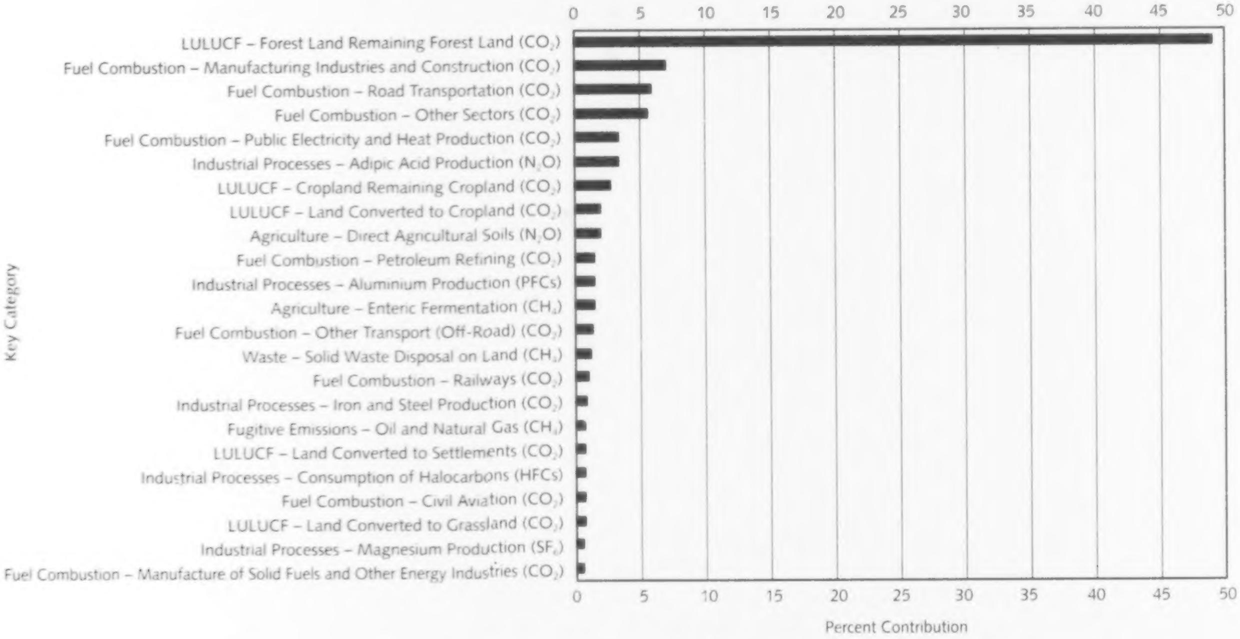
Source Table	IPCC Categories	Direct GHG	1990 (Base Year) kt CO_2 eq	2003 (Current Year) kt CO_2 eq	Trend Assessment	Contribution to Trend %	Cumulative Total %
5-A.1	LULUCF – Forest Land Remaining Forest Land[2]	CO_2	-187 838	-69 578	0.206	49	49
1-A-2	Fuel Combustion – Manufacturing Industries and Construction	CO_2	62 368	65 495	0.030	7.1	56
1-A-3-b	Fuel Combustion – Road Transportation	CO_2	102 878	134 557	0.025	6.0	62
1-A-4	Fuel Combustion – Other Sectors	CO_2	69 415	83 802	0.023	5.5	68
1-A-1-a	Fuel Combustion – Public Electricity and Heat Production	CO_2	94 745	133 379	0.014	3.4	71
2-B-3	Industrial Processes – Adipic Acid Production	N_2O	10 718	1 085	0.014	3.4	75
5-B.1	LULUCF – Cropland Remaining Cropland[2]	CO_2	7 208	-1 512	0.012	2.8	77
5-B.2	LULUCF – Land Converted to Cropland	CO_2	15 961	15 961	0.008	2.0	79
4-D	Agriculture – Direct Agricultural Soils	N_2O	21 758	25 365	0.008	1.9	81
1-A-1-b	Fuel Combustion – Petroleum Refining	CO_2	25 977	33 675	0.007	1.6	83
2-C-3	Industrial Processes – Aluminium Production	PFCs	6 297	2 741	0.007	1.6	84
4-A	Agriculture – Enteric Fermentation	CH_4	18 682	22 410	0.006	1.5	86
1-A-3-e	Fuel Combustion – Other Transport (Off-Road)	CO_2	15 086	17 648	0.006	1.3	87
6-A	Waste – Solid Waste Disposal on Land	CH_4	18 530	23 702	0.005	1.2	88
1-A-3-c	Fuel Combustion – Railways	CO_2	6 315	5 262	0.004	1.0	89
2-C-1	Industrial Processes – Iron and Steel Production	CO_2	7 058	7 041	0.004	0.9	90
1-B-2-(a+b)	Fugitive Emissions – Oil and Natural Gas	CH_4	25 685	37 084	0.003	0.7	91
5-E.2	LULUCF – Land Converted to Settlements	CO_2	5 667	5 667	0.003	0.7	92
2-F	Industrial Processes – Consumption of Halocarbons	HFCs	0	3 090	0.003	0.7	92
1-A-3-a	Fuel Combustion – Civil Aviation	CO_2	6 216	7 001	0.003	0.6	93
5-C.2	LULUCF – Land Converted to Grassland	CO_2	4 755	4 755	0.002	0.6	94
2-C-4-2	Industrial Processes – Magnesium Production	SF_6	2 870	2 232	0.002	0.5	94
1-A-1-c	Fuel Combustion – Manufacture of Solid Fuels and Other Energy Industries	CO_2	23 555	34 842	0.002	0.5	95

Notes:

[1] IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Chapter 7, Tier 1 Analysis - Trend Assessment - Sorted by % Contribution to Trend.

[2] The negative values for LULUCF – Forest Land Remaining Forest Land and LULUCF – Cropland Remaining Cropland indicate net removals. According to IPCC (2003), the absolute values were used in the assessment.

FIGURE A1-4: Contributions of Key Categories to Trend Assessment with LULUCF



A1.2.5 QUALITATIVE ASSESSMENT

A1.2.5.1 Mitigation Techniques and Technologies

Mitigation techniques are important for good practices, in particular if they are inclined to produce departures from the norm under which activity data and emission factors are estimated. Table A1-6 shows key categories identified as a result of having significant mitigation techniques and technologies introduced that have had (since 1990), or will have, an impact on emission estimates.

TABLE A1-6: Key Categories by Significant Mitigation Techniques and Technologies

Key Category	GHG	References	Comments
Fugitive Emissions – Oil and Natural Gas – Venting and Flaring	CO_2	NCCS, 2000b	Upstream oil and gas industry is planning to reduce flaring by 50% by 2006 with use of micro turbines: Voluntary measure
Fuel Combustion – Road Transportation	CO_2	Government of Canada, 2000, NCCS, 2000a	Voluntary efficiency standards, increased biofuel use: Voluntary measure
Fuel Combustion – Public Electricity and Heat Production	CO_2	NRCan, 1999; Government of Canada, 2000, 2005; NCCS, 2000a	Utility deregulation opens market to distributed power and reduced barriers to interprovincial trade. Natural gas replaces coal and oil generation: Voluntary measure. Wind Power Production Incentive – 4000 MW of wind power by 2010: Budget incentive to displace fuel
Fuel Combustion – Manufacture of Solid Fuels and Other Energy Industries	CO_2	Government of Canada, 2000; NCCS, 2000a	Demonstrate CO_2 capture and storage: Voluntary measure
Waste – Solid Waste on Land	CH_4	CSA, Online; Environment Canada, Online	Landfills are collecting CH_4 emissions for combustion or power generation: Policy measure
Fugitive Emissions – Oil and Natural Gas – Venting and Flaring	CH_4	NCCS, 2000b	Upstream oil and gas industry is reducing pipeline and exploration venting: Voluntary measure
Industrial Processes – Adipic Acid Production	N_2O	Lauridson, 2004	An emission abatement system was installed at Canada's only adipic acid production facility in 1997. As a result, emissions from this source have decreased by 90% from 1990 to 2003.
Industrial Processes – Magnesium Production	SF_6	NRCan, 1999	Gradual replacement of SF_6 in magnesium casting and smelting by alternative cover gases: Voluntary measure
Cropland Remaining Cropland	CO_2	Government of Canada, 2005	Cropland management – Increasing adoption of conservation tillage and reducing summer-fallow

A1.2.5.2 High Emissions Growth

Table A1-7 shows key categories identified as a result of having emissions growth forecasts of over 20% between 1997 and 2020. Designation as key anticipates significant changes in the sector and indicates a need to establish sound estimating practices.

TABLE A1-7: Key Categories Identified from Anticipated High Emissions Growth

Key Source	GHG	Reference	Comments
Fuel Combustion – Manufacture of Solid Fuels and Other Energy Industries	CO_2	NRCan, 1999	Increased heavy oil production
Fuel Combustion – Petroleum Refining	CO_2	NRCan, 1999; NCCS, 2000a	Increased heavy oil use
Fuel Combustion – Transport – Road	CO_2	NRCan, 1999	Growth in road transport use
Fuel Combustion – Transport – Civil Aviation	CO_2	NRCan, 1999	Growth in air travel, passenger and freight
Fuel Combustion – Transport – Civil Aviation	N_2O	NRCan, 1999	Growth in air travel, passenger and freight
Fuel Combustion – Transport – Civil Aviation	CH_4	NRCan, 1999	Growth in air travel, passenger and freight
Fuel Combustion – Transport – Other	CO_2	NRCan, 1999	Growth in off-road use, especially fossil fuel mining
Fuel Combustion – Transport – Road	N_2O	NRCan, 1999	Growth in road transport use
Consumption of HFCs and SF_6	HFCs	NRCan, 1999	Increase due to replacement of CFCs

A1.2.5.3 High Uncertainty

The ICF (2004) study of uncertainty associated with 2001 inventory estimates is the most current source of information for key sources based on uncertainty levels. In this study, uncertainties are reported following the UNFCCC CRF categories. Table A1-8 shows key categories identified as having a relatively high composite uncertainty (meaning both activity and emission factor uncertainties) compared with the expected norm (see estimates in the tables of Annex 7).

TABLE A1-8: Key Categories with a High Composite Uncertainty

Key Source	GHG	Reference
Fuel Combustion – Manufacturing of Solid Fuels and Other Energy Industries	CO_2	ICF, 2004
Fuel Combustion – Petroleum Refining	CO_2	ICF, 2004
Waste – Solid Waste Disposal on Land	CH_4	ICF, 2004
Waste – Waste Incineration	CO_2	ICF, 2004
Agriculture – Direct Agricultural Soils	N_2O	ICF, 2004
Agriculture – Indirect Agricultural Soils	N_2O	ICF, 2004
Waste – Wastewater Handling	N_2O	ICF, 2004
Fuel Combustion – Off-Road: Diesel	N_2O	ICF, 2004
Fuel Combustion – Rail	N_2O	ICF, 2004
Fuel Combustion – Road	CO_2	ICF, 2004
Fuel Combustion – Off-Road: Diesel	CO_2	ICF, 2004
Fuel Combustion – Off-Road: Gasoline	CO_2	ICF, 2004
Fuel Combustion – Marine (Navigation)	N_2O	ICF, 2004
Fuel Combustion – Aviation	N_2O	ICF, 2004
Fuel Combustion – Off-Road: Gasoline	CH_4	ICF, 2004
Industrial Processes – Other and Undifferentiated Production	CO_2	ICF, 2004
Industrial Processes – Ammonia Production	CO_2	ICF, 2004
Industrial Processes – Lime Production	CO_2	ICF, 2004

A1.2.6 SUMMARY ASSESSMENT

The results of key category assessment in accordance with both IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000) and the IPCC *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003) are given in Table A1-1.

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ANNEX 2: METHODOLOGY AND DATA FOR ESTIMATING EMISSIONS FROM FUEL COMBUSTION

To estimate emissions from fuel combustion, the following methodology has been adopted. It applies, generally, to all source sectors, although additional refinements and more detailed procedures are often used.

Equation A2-1:

Emissions = Quantity of Fuel Combusted × Emission Factor per Physical Unit of Fuel

For each sector and subsector, the appropriate quantity of each fuel combusted is multiplied by a fuel- and technology-specific emission factor.

The emission factors employed in estimating the emissions for the current GHG inventory are listed in Annex 7:

- *Natural Gas Fuels*: The emission factors vary by fuel type and combustion technology.
- *Refined Petroleum Product Fuels*: The emission factors vary by fuel type and combustion technology.
- *Coal Fuels*: The emission factors for CO_2 vary with the properties of the coal. Therefore, emission factors are assigned for different provinces based upon the origins of the coal used. The emission factors for CH_4 and N_2O vary with the combustion technology.

This is consistent with an IPCC Tier 2-type methodology, as described in the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997).

A2.1 CO_2 EMISSIONS

Fuel combustion CO_2 emissions depend upon the amount of fuel consumed, the carbon content of the fuel, and the fraction of the fuel oxidized (Jaques, 1992). The basis of the CO_2 emission factor derivations has been discussed in previous publications (e.g., Jaques, 1992). The factors have been obtained and developed from a number of studies conducted by Environment Canada, the U.S. EPA, and other organizations, both domestic and international. The methods used to derive the factors are based on the carbon contents of the fuels and the typical fraction of carbon oxidized. Both the hydrocarbons and particulate formed during combustion are accounted for to some extent, but emissions of CO are included in the estimates of CO_2 emissions. It is assumed that CO in the atmosphere undergoes complete oxidation to CO_2 shortly after combustion (within 5–20 weeks of its release).

Emission factors are based upon the physical quantity of fuel combusted, rather than on the energy content of the fuel. They therefore provide a more accurate estimate of emissions, since the number of conversions required to derive the estimates is minimized and since quantity of fuel consumed is commonly reported in physical units to Canada's statistical agency (i.e., Statistics Canada) and is therefore assumed to be more accurate. It is important to note that these Canadian-specific emission factors differ from those of the IPCC in that they relate emissions to the quantity of fuel consumed and not to the energy content of the fuel. The emission factors employed to estimate emissions are subdivided by the type of fuel used.

A2.2 NON-CO_2 GHGs

Emission factors for all non-CO_2 GHGs from combustion activities vary to a lesser or greater degree with:

- fuel type;
- technology;
- operating conditions; and
- maintenance and vintage of technology.

During combustion of carbon-based fuels, a small portion of the fuel remains unoxidized as CH_4. Additional research is necessary to better establish CH_4 emission factors for many combustion processes. Overall factors are developed for sectors based on typical technology splits and available emission factors for the sector. In several sectors, CH_4 emission factors are not known.

During combustion, some of the nitrogen in the fuel or air is converted to N_2O. The production of N_2O is dependent upon the temperature in the boiler/stove and the control technology employed. Additional research is necessary to better establish N_2O emission factors for many combustion processes. Overall factors are developed for sectors based on typical technologies and available emission factors for the sector. In several sectors, N_2O emission factors are not known. Non-CO_2 emission factors in this inventory are listed in Annex 13.

A2.3 BIOMASS COMBUSTION

Some emissions of CO_2 result from the combustion of biomass used to produce energy. However, as per UNFCCC requirements, CO_2 emissions from biomass fuels are not included in the Energy Sector totals. They are accounted for in the LULUCF Sector as a loss of biomass (forest) stocks. CO_2 from biomass combustion for energy purposes is reported as a memo item for information only. CH_4 and N_2O emissions from biomass fuel combustion are reported in the Energy Sector in the appropriate subsectors and included in inventory totals.

A2.4 STATISTICS CANADA ENERGY-USE DATA — RESD

The fossil fuel energy-use data used to estimate combustion emissions are from the RESD (Statistics Canada, #57-003), compiled by Statistics Canada, Canada's national statistics agency. It is the principal source of energy-use data.

The RESD uses a top-down approach to estimate the supply and demand of energy in Canada. The production of fuels in Canada is balanced with the use of fuels in broad categories such as import/export, producer consumption, industry, residential, etc. Industrial energy-use data are divided into broad sectors based on SIC or NAICS codes.

While the RESD also provides fuel-use estimates at a provincial level, the accuracy of these data is not as high as that of the national data. Statistics Canada generally collects the fuel data for the RESD by surveying the suppliers of energy, provincial energy ministries, and some users of energy. The accuracy of the sectoral end-use data is less than that of the total energy supply data. As a result, the total emission estimates for Canada are known with more certainty than the emissions from specific categories. Since 1995, Statistics Canada has been collecting energy-use statistics from end users through the Industrial Consumption of Energy survey. This bottom-up approach to estimating fuel use by industry (as opposed to the top-down approach used in the RESD) may provide more accurate information at the sector level for future inventories.

REFERENCES

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ANNEX 3: ADDITIONAL METHODOLOGIES

A3.1 METHODOLOGY FOR AGRICULTURE

The Agriculture Sector generates three sources of emissions: enteric fermentation, manure management, and agricultural soils. Due to changes to the reporting guidelines, emissions and removals of CO_2 from agricultural soils are now reported under the LULUCF Sector. This section of Annex 3 describes the detailed accounting methodologies (i.e., specific equations, models, activity data, and emission factors) that are used to derive the GHG estimates for the following sources of the Agriculture Sector:

- CH_4 emissions from enteric fermentation;
- CH_4 and N_2O emissions from manure management; and
- N_2O emissions from agricultural soils.

N_2O emissions from agricultural soils are further divided into direct emissions — associated with synthetic fertilizer, manure application, crop residue decomposition, nitrogen-fixing plants, cultivation of organic soils, and manure on pasture and paddock — and indirect emissions off site from volatilization, leaching, and runoff of nitrogen contained in synthetic fertilizer and manure.

A3.1.1 METHANE EMISSIONS FROM ENTERIC FERMENTATION

A3.1.1.1 Methodology

To estimate CH_4 emissions from enteric fermentation, the IPCC Tier 2 methodology is used for dairy and beef cattle, and the IPCC Tier 1 methodology is used for the other animal categories. Equation A3-1 is used to calculate the release of CH_4 from enteric fermentation from different categories of livestock in Canada.

Equation A3-1:

$$CH_{4EF} = \sum_{Types} \left(N_T \ast EF_{(EF)T}\right)$$

where:

CH_{4EF} = enteric fermentation emissions for all animal categories

N_T = animal population for each specific animal category or subcategories (by province)

$EF_{(EF)T}$ = emission factor for each specific animal category *Refer to Table A3-1*

TABLE A3-1: Enteric Fermentation Emission Factors

Animal Category	Emission Factors $EF_{(EF)T}$ *kg CH_4/head per year*
Cattle	
Bulls	94[1]
Dairy Cows	126[1]
Beef Cows	90[1]
Dairy Heifers	73[1]
Beef Heifers	75[1]
Heifers for Slaughter	63[1]
Steers	56[1]
Calves	40[1]
Pigs	
Swine	1.5[2]
Other Livestock	
Sheep	8[2]
Lambs	8[2]
Goats	5[2]
Horses	18[2]
Buffaloes	55[2]

Notes:

1 Emission factors are derived from Boadi et al. (2004) following the guidelines provided by IPCC (2000).

2 IPCC Tier 1 default emission factors (IPCC/OECD/IEA, 1997).

Determining Methane Enteric Emission Factors for Various Categories of Cattle Using IPCC Tier 2 Methodology

The IPCC Tier 2 method is used to determine enteric CH_4 emission factors for beef and dairy cattle in Canada. To achieve this, it was first necessary to characterize the cattle population according to animal type, physiological status, age, gender, weight, rate of gain, level of activity, and production environment. Much of this information was not available in the published literature and required contact with beef and dairy cattle specialists across the country. This information was used to calculate emission factors associated with various cattle categories based on the IPCC Tier 2 equations (Boadi et al., 2004), and then in conjunction with Statistics Canada population data to generate estimates of enteric emissions for each province.

Characterization of Canadian Cattle Production Practices

When available, data from surveys examining production and management practices that have been published in scientific journals were utilized to describe the production environment and associated performance of classes of animals. Given that this information was not available for all classes of cattle, a survey of dairy and beef production practices was created and administered to cattle specialists who

TABLE A3-2: Characteristics of Dairy Production in Canada

Animal Category/Parameters	Production Characteristics[1]	Data Sources[2]
Dairy Cows		
Average weight, kg	634 (51)	Okine and Mathison, 1991; Kononoff et al., 2000; Petit et al., 2001
Mature weight, kg	646 (55)	–
Daily weight gain, kg/day	0.25 (0.11)	–
Daily weight loss, kg/day	0.98 (0.27)	Parker, 1989
Milk, kg/day	29.0 (2.3)	Plaizier et al., 2001; Veira et al., 2001; Thivierge et al., 2002; Western DHI, 2002; Ontario DHI, 2003
Milk fat, %	3.6 (0.2)	Veira et al., 2001; Western DHI, 2002; Ontario DHI, 2003
Conception rate, %	59.2 (7.3)	–
Calculated pregnant, %	58.4 (1.2)	–
Days in milk	350 (4.3)	Western DHI, 2002
Days dry	77 (7)	Western DHI, 2002
Calves		
Birth weight, kg	41 (3.3)	–
Average weight, kg	186 (18.5)	–
Mature weight, kg	330.5 (37.6)	–
Daily weight gain, kg/day	0.7 (0.3)	–
Calf crop,[3] %	93 (6)	–
Replacement Heifers		
Average weight, kg	461.6 (24.7)	–
Beginning weight — 1 year, kg	327.8 (31.0)	–
Mature weight at calving, kg	602.1 (45.9)	–
Mature weight for equation, kg	646.1 (54.9)	–
Daily gain, kg/day	0.77 (0.14)	–
Replacement rate, %	32.3 (3.2)	Western DHI, 2002

Notes:

1 The numbers in parentheses are the standard deviation.

2 Values with no reference were obtained from expert consultations (see Boadi et al., 2004).

3 Calf crop is the percentage of the overwintering cows that produced a live calf.

were identified at the regional and/or provincial level in each province. Additional information was sought from research scientists at universities/federal research institutions, as well as from provincial/national commodity groups and provincial/regional performance recording organizations.

- **Production Practices and Performance for Dairy Cattle**

A summary of the production performance of Canadian dairy cattle is provided in Table A3-2.

Production practices utilized in some provinces were variable across the province as a consequence of differences in land value, climate (precipitation), forage availability, market access, etc. Those practices that predominated across a given province were utilized in the IPCC Tier 2 equations.

Milk Yield Data

Western Dairy Herd Improvement (DHI) records for milk yield were available for Manitoba, Saskatchewan, Alberta, and British Columbia. DHI records were also available for Ontario, Quebec, Nova Scotia, and Prince Edward Island. Survey data were used for New Brunswick and Newfoundland and Labrador. These values were used to calculate $NE_{lactation}$ (NE_l) (see Equation A3-8).

Milk Fat Data

Western DHI records for milk fat (%) were available for Manitoba, Saskatchewan, Alberta, and British Columbia. DHI records were also available for Ontario, Quebec, Nova Scotia, and Prince Edward Island. Survey data were used for New Brunswick and Newfoundland and Labrador. These values were used to calculate NE_l (see Equation A3-8).

Weight Loss and Gain

Weight loss values were assumed to occur in the first 70 days of lactation for all provinces except Newfoundland and Labrador. Survey data from this province indicated that weight loss occurred in the first 56 days. Further, a weight loss of 0.75 kg/day was assumed for cows in Quebec. This is the value that was obtained from the Ontario survey, as no weight loss data were available from the Quebec survey.

Duration of Time in a Production Environment

Dry cows are both on pasture and fed in confinement in Ontario and Newfoundland and Labrador. It was assumed that animals that were dry during the summer months were on pasture and that animals that were dry during the remainder of the year were in confinement. Further, replacement heifers were assumed to calve at 24 months, although in some circumstances they may have been greater than 24 months of age at calving.

Cow Replacement Rate

Cow replacement rate data were not available for the province of Ontario; therefore, a value of 34.6% was estimated using the replacement rate from Quebec.

Percentage of Cows Pregnant

An estimate of the percentage of cows that were pregnant in the herd at any given time was calculated according to J.C. Plaizier (personal communication, 2004) using the following formula:

Percent cows pregnant = (gestation length/calving interval × 100) - percent cows culled due to reproductive failure

- **Production Practices and Performance for Beef Cattle**

A summary of the production performance of Canadian beef cattle is provided in Table A3-3.

Milk Yield

As no milk yield data were available for Ontario, Quebec, New Brunswick, Nova Scotia, and Prince Edward Island, Manitoba milk yield data were utilized for these provinces.

Milk Fat

As no milk fat data were available for Ontario, Quebec, New Brunswick, Nova Scotia, and Prince Edward Island, Manitoba data were utilized for these provinces.

Average Weight

Average weights were not available for beef cows, replacement heifers, or bulls in Quebec. Ontario values were utilized in lieu of these values.

Weight Loss

Weight loss in beef cows was assumed for the first two months of lactation for mature cows. Although this may not be an appropriate assumption for first-calf heifers, the same assumption was made, as heifer weight loss data were not available. Weight loss data for cows were not available for Newfoundland and Labrador and Quebec. Ontario weight loss data were utilized for these provinces.

TABLE A3-3: Characteristics of Beef Production in Canada

Animal Category/Parameters	Production Characteristics[1]	Data Sources[2]
Beef Cows		
Average weight, kg	603 (36)	Kopp et al., 2004
Mature weight, kg	619 (52)	AAFRD, 2001
Daily weight gain, kg/day	0.35 (0.12)	Kopp et al., 2004
Daily weight loss, kg/day	0.46 (0.32)	–
Milk, kg/day	7.3 (1.2)	Kopp et al., 2004
Milk fat, %	3.6 (0.6)	Kopp et al., 2004
Conception rate, %	93.7 (1.3)	Manitoba Agriculture and Food, 2000; AAFRD, 2001
Replacement Heifers		
Average weight, kg	478 (34)	–
Mature weight, kg	620 (51)	–
Daily weight gain, kg/day	0.64 (0.14)	–
Replacement rate, %	14.4 (3.1)	Manitoba Agriculture and Food, 2000
Bulls		
Yearling weight, kg	541 (18)	–
Average weight, kg	923 (98)	–
Mature weight, kg	951 (112)	–
Daily weight gain, kg/day	1.0 (0.17)	–
Calves (including dairy calves)		
Birth weight, kg	40 (3)	AAFRD, 2001
Wean weight, kg	258.4 (19.1)	Small and McCaughey, 1999; Alberta Beef Producers, 2004
Age at weaning, days	215 (15)	–
Daily weight gain, kg/day		
Replacement heifers	0.67 (0.13)	Kopp et al., 2004
Backgrounder	0.98 (0.17)	–
Finisher	1.37 (0.12)	–
Calf crop,[3] %	95 (2.3)	–
Heifer and Steer Stockers		
Average weight, kg	411 (47)	Kopp et al., 2004
Mature weight, kg	620 (51)	–
Daily weight gain, kg/day	0.98 (0.16)	–
Proportion to feedlot, %	65 (30)	–
Feedlot Animals		
Average weight, kg	-	–
Direct finish	540 (25)	–
Background finish	562 (64)	–
Mature weight, kg	630 (46)	–
Finish weight, kg	609 (28)	–
Daily weight gain, kg/day	1.37 (0.12)	–

Notes:

1 The number in parentheses is the standard deviation.

2 Values with no reference were obtained from expert consultations (see Boadi et al., 2004).

3 Calf crop is the percentage of the overwintering cows that produced a live calf.

Weight Gain

Average daily weight gain for cows and replacement heifers was not available for Quebec. As such, Ontario data were used in lieu of these values.

Replacement Rate of Seedstock

Replacement rates for heifers and proportion of young versus mature bulls were not available for Quebec. Ontario data were used in lieu of these values.

Duration of Time in a Production Environment

Calves are assumed to have a non-functional rumen or to consume very small amounts of dry feed (mostly milk) from birth until they reach two to three months of age. Therefore, enteric CH_4 emissions in these first few months were assumed to be zero. Replacement heifers over 15 months of age were assumed to be bred or pregnant. All replacement stock (breeding bulls, young and replacement heifers over 12 months of age) was assumed to enter the breeding herd (breeding bulls, mature and beef cows) at 24 months of age.

Characterization of the Feeding Strategies for Beef and Dairy Cattle

When available, data from surveys examining feeding management practices that had subsequently been published in scientific journals were utilized to describe the feeding strategies for classes of animals. Additional information was sought from research scientists at universities/federal research institutions, as well as from provincial/national commodity groups and provincial/regional performance recording organizations.

- **Ration Digestible Energy (DE) Calculations for Dairy Cattle**

Forage DE values determined by Christensen et al. (1977) for forages grown on the prairies were used to estimate ration DE for Alberta, Saskatchewan, and Manitoba. Values from NRC (2001) were used to estimate ration DE for British Columbia, the eastern provinces, and the Maritimes. Total mixed rations for cattle were assumed to be mainly forage and grain due to limited information regarding other feed ingredients. It was also assumed that lactating cows on pasture were supplemented with grain; therefore, DE values were assumed to be similar to those of rations fed in confinement.

- **Forage:Grain Ratios for Dairy Cattle**

In Saskatchewan and Alberta, dry cow transition diet forage:grain ratios were estimated using Manitoba's forage:grain ratios, with an assumed transition period of three weeks.

- **Ration DE Calculations for Beef Cattle**

Forage DE values determined by Christensen et al. (1977) for forages utilized on the prairies were used to estimate ration DE for Saskatchewan and Manitoba. Values from AAFRD (2003) were used for Alberta, while NRC (2001) values were used to estimate DE of rations from British Columbia, the eastern provinces, and the Maritimes.

Calculating Enteric Methane Emissions Using IPCC Tier 2 Methodology

Equations used to calculate enteric CH_4 emissions were taken from IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). To obtain emission factors for different categories of cattle (dairy cows, dairy heifers, beef cows, beef heifers, bulls, calves, heifer replacement, heifers > 1 year, and steers >1 year), it was necessary to examine emissions at different stages of production. Dairy cattle, for example, have two subcategories — dry cows and lactating cows. Emission factors (kg CH_4/head per year) for the subcategories were determined by dividing the generated enteric emissions for each production time (t/year) by the animal population. As the duration of time that an animal was in a category was variable for some categories, a weighted emission factor was calculated. Criteria used in the weighting included duration of time in the category and relative percentage of the population in each stage of production. Provincial emission factors weighted on the basis of provincial contribution to the national animal inventory were used to calculate a national emission factor for each category (Table A3-4).

TABLE A3-4: Provincial and National CH_4 Emission Factors Associated with Various Cattle Categories in Canada

	Dairy Cows	Dairy Heifers	Beef Cows	Bulls	Calves <1 year	Heifer Replacement	Heifers >1 year	Steers >1 year
BC	144	72	95	106	37	82	64	59
AB	127	71	93	96	43	76	65	59
SK	127	75	77	87	37	61	55	50
MB	134	72	94	93	33	73	60	55
ON	130	75	105	90	40	90	60	55
QC	119	70	104	96	42	97	41	38
NL	122	93	85	105	45	68	99[3]	91[3]
NB	131	77	98	96	39	80	46	42
NS	119	78	90	84	41	68	70	64
PE	125	75	88	88	33	71	48	44
Range	119–144	70–93	77–105	84–106	33–45	61–97	41–70	38–64
Mean[1]	126	73	90	94	40	75	63	56
Standard Deviations[2]	7 (5%)	7 (9%)	8 (9%)	7 (8%)	4 (10%)	11 (14%)	10 (17%)	9 (17%)

Notes:

1 Weighted means for each dairy and beef category based on animal population. These values were used as national average values (Table A3-1).

2 Number in parentheses expressed as percentage of the mean.

3 Value is outside the expected range and was not used in deriving the mean.

Source: Boadi et al. (2004).

TABLE A3-5: Data Sources for Animal Populations

Animal Category	Data Source
Cattle	
Bull, Dairy Cow, Beef Cow, Dairy Heifer, Beef Heifer for Slaughter, Steer, and Calves	Statistics Canada (2004a), Catalogue No. 23-603-XIE, Table 1, Cattle and Calves on Farms
Pigs	
Boar, Sow, Pig (<20 kg), Pig (20–60 kg), and Pig (>60 kg)	Statistics Canada (2004a), Catalogue No. 23-603-XIE, Table 1, Pigs on Farms
Goats, Horses, and Buffaloes	Statistics Canada, 1991, 1996, 2001 Census of Agriculture, Catalogue No. 93-350, 93-356, and 95F0301, Table 22.1, Statistics Canada (1992, 1997, 2002). Other Livestock and Colonies of Bees, by Province, Census Agricultural Region and Census Division
Poultry	
Chickens and Turkeys	Statistics Canada, 1991, 1996, 2001 Census of Agriculture, Catalogue No. 93-350, 93-356, and 95F0301, Table 23.1, Statistics Canada (1992, 1997, 2002). Poultry Inventory, by Province, Census Agricultural Region and Census Division
Poultry	
Hens	Statistics Canada (2003b), Catalogue No. 23-202-XIB, Table 5, Production of Eggs Yearly Average
Other Livestock	
Sheep and Lambs	Statistics Canada (2004a), Catalogue No. 23-603-XIE, Table 1, Sheep and Lambs on Farms

A3.1.1.2 Data Sources

Annual livestock population data at a provincial level are used to develop emission estimates. Table A3-5 is a list of livestock and their corresponding data sources.

A3.1.1.3 Livestock Population Adjustments

The following adjustments are made to convert livestock population data to an annual basis. These adjustments are necessary for cattle, pig, and sheep/lamb data, since they are collected on a quarterly or a semiannual basis. Horse, goat, and buffalo populations are censused on a five-year basis. In order to avoid large annual changes, especially for years immediately before the Census year, and based on the UNFCCC 2003 in-country review recommendation, horse, goat, buffalo, turkey, and chicken populations have been adjusted using the interpolation method. In addition, buffalo population data were not collected in 1991; thus, the buffalo population was set constant at the 1996 level since 1990.

Cattle data are reported semiannually by Statistics Canada; therefore, livestock population adjustments are necessary. Cattle populations are collected for January and July for each inventory year. Average cattle population distribution is calculated using the equation shown below for each cattle type:

Equation A3-2:

$$\overline{\text{Cattle Population}} = \left(\frac{\text{Cattle Population (January + July)}}{2}\right)$$

Pig population data are collected on a quarterly basis; therefore, population data adjustments are necessary. The annual pig population is calculated using Equation A3-3:

Equation A3-3:

$$\overline{\text{Pig Population}} = \left(\frac{\text{Pig Population (January + April + July + October)}}{4}\right)$$

Statistics Canada collects population data on sheep and lambs on a semiannual basis; therefore, population data adjustments are necessary. The annual sheep/lamb population is calculated using Equation A3-4:

Equation A3-4:

$$\overline{\text{Sheep \& Lamb Population}} = \left(\frac{\text{Sheep \& Lamb Population (January + July)}}{2}\right)$$

A3.1.2 METHANE EMISSIONS FROM MANURE MANAGEMENT

The IPCC Tier 2 methodology is used to estimate CH_4 emissions from manure management. Equation A3-5 is used to calculate CH_4 emissions from manure management for different categories of livestock in Canada:

Equation A3-5:

$$CH_{4_{MM}} = \sum_{Types} (N_T * EF_{(MM)T})$$

where:

$CH_{4_{MM}}$ = emissions for all animal categories

N_T = animal population for each specific animal category (by province)

$EF_{(MM)T}$ = emission factor for each specific animal category

Sources of animal population data are the same as those used in the Enteric Fermentation estimations (see above).

A3.1.2.1 Determining Methane Emission Factors for Various Animal Categories Based on Manure Management Practices Using IPCC Tier 2 Methodology

The IPCC Tier 2 method for estimating CH_4 emissions from manure management systems has been developed and outlined in *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). This approach uses country-specific inputs that should result in more accurate estimates. The IPCC Tier 2 method takes into account livestock diet, type and distribution of manure storage, and climate.

Equation A3-6 represents an IPCC Tier 2 estimate of CH_4 emission factors from manure management systems:

Equation A3-6:

$$EF_{(MM)T} = VS_T * 365 \text{ days/year} * B_{oT} \times 0.67 \text{ kg/m}^3 * \textstyle\sum_{ij} (MCF_{ij} * MS_{Tij})$$

where:

$EF_{(MM)T}$ = annual emission factor for defined animal population T in kg

VS_T = daily volatile solids excreted for an animal within the defined population T in kg

B_{oT} = maximum CH_4 producing potential for manure produced by an animal within defined population T in m^3/kg VS

MCF_{ij} = CH_4 conversion factor for each manure management system i by climate region j

MS_{Tij} = system distribution factor, defined as the fraction of animal category T's manure that is handled using manure system i in climate region j
(IPCC, 2000: Equation 4.17, p. 4.34)

Table A3-6 presents a list of emission factors derived from a recent study by Marinier et al. (2004). The following sections examine the data sources for volatile solids (VS) production, maximum CH_4 production potential (B_o), and methane conversion factors (MCF) for major animal categories. An estimate of the uncertainty associated with these inputs was also calculated using Monte Carlo simulations (Decisioneering Inc., 2000).

Volatile Solids

Volatile solids (VS) are the organic fraction of total solids within the manure and can be measured from manure samples, although this is rarely done in Canada. Alternatively, volatile solids can be estimated using the IPCC methodology (IPCC, 2000) based on diet intake:

Equation A3-7:

$$VS = DMI * (1 - DE/100) * (1 - ASH/100)$$

where:

VS = volatile solids excretion (kg/head per day)

DMI = ration dry matter intake (kg/head per day)

DE = digestible energy of the ration, expressed as a percent (%)

ASH = mineral content of the manure (%)
(IPCC, 2000: Equation 4.16, p. 4.31)

TABLE A3-6: Manure Management CH_4 Emission Factors for Various Domestic Livestock in Canada

Animal Category	Emission Factors[3] $EF_{(MM)T}$ *kg CH_4/head per year*
Cattle	
Bulls[1]	10.8 (±35%)
Dairy Cows	32.5 (±41%)
Beef Cows	3.4 (±26%)
Dairy Heifers	17.8 (±39%)
Beef Heifers	2.4 (±28%)
Heifers for Slaughter	2.0 (±29%)
Steers	2.0 (±29%)
Calves[1]	0.98 (±28%)
Swine	
Boars	7.3 (±34%)
Sows	14.6 (±41%)
Pigs (<20 kg)	1.3 (±56%)
Pigs (20–60 kg)	5.9 (±36%)
Pigs (>60 kg)	9.2 (±36%)
Poultry	
Chickens	0.02 (±50%)
Hens	0.13 (±31%)
Turkeys	0.02 (±50%)
Other Livestock	
Sheep	0.36 (±33%)
Lambs	0.21 (±33%)
Goats	0.22 (±36%)
Horses	2.1 (±29%)
Buffaloes[2]	2.0 (±29%)

Notes:

1 Emission factors for bulls and calves are initially estimated separately for dairy and beef. Because animal populations are reported all together for both dairy and beef in the Census, weighted emission factors for bulls and calves are provided based on an assumption that the ratio of dairy to beef for bulls and calves is the same as that for cows, approximately 1:2.

2 Emission factor for buffaloes is assumed to be the same as for steers.

3 Values in parentheses are estimates of uncertainty as a percentage of the mean generated using a Monte Carlo approach (see Marinier et al., 2004).

To estimate VS according to the IPCC methodology (IPCC, 2000), an estimate of ration dry matter intake (DMI) is essential. Ration dry matter intake in livestock depends on many factors, including body size, lactation stage, and time of year (summer versus winter). An estimate of DMI was obtained by Marinier et al. (2004) through consultation with livestock nutritionists and U.S. National Research Council publications. In the case of ruminants, IPCC recommends calculating gross energy to estimate DMI. The following equation is presented to estimate gross energy intake:

Equation A3-8:

$$GE = \{[(NE_m + NE_a + NE_l + NE_p)/(NE_{ma}/DE)] + [NE_g/(NE_{ga}/DE)]\}/(DE/100)$$

where:

GE = gross energy (MJ/day)
NE_m = net energy required for maintenance (MJ/day)
NE_a = net energy required for activity (MJ/day)
NE_l = net energy for lactation (MJ/day)
NE_p = net energy required for pregnancy (MJ/day)
NE_{ma}/DE = ratio of net energy available in a diet for maintenance to digestible energy
NE_{ga}/DE = ratio of net energy available for growth in a diet to digestible energy consumed
DE = digestible energy of the ration, expressed as a percent (%)
(IPCC, 2000: Equation 4.11, p. 4.20)

Once GE is calculated, a feed energy factor of 18.45 MJ/kg is recommended by IPCC to convert the values into DMI. Some ruminant nutritionists in Canada argued that Equation A3-8 was not an acceptable model for estimating intake. Each parameter in Equation A3-8 contains error, which may be difficult to assess. Some of the input values for the parameters are default values provided by IPCC (2000), but are inadequately referenced and without discussion of uncertainty. Other parameter inputs (e.g., daily milk production) are widely variable and may cause large error. The accumulated error of the whole equation may therefore be quite difficult to assess. It was decided by Marinier et al. (2004) that DMI values obtained from expert opinion and published sources were more appropriate and easier to assess than calculating values with Equation A3-8. The following sections outline the input values for Equation A3-7: diet digestibility, manure ash content, dry matter intake, and volatile solids.

- **Digestible Energy (DE)**

Broad regional differences in ration composition were identified for cattle (dairy and beef), sheep, horses, and swine. Regional differences were not considered for goats or poultry, since such data were not available.

Generally, rations for grazing livestock consist of grains, roughage (pasture, hay, etc.), or a combination of both. Diet digestibility will vary, with grains having a higher digestibility than roughage. With the annual feed usage data presented in Statistics Canada (2003a), the distribution of grain-based and roughage-based diets was estimated for dairy cattle, beef cattle, sheep, and horses in each province. Knowing the approximate DE for grains and roughage for each animal and the distribution of grain and roughage usage by province, a weighted estimate of DE was obtained (Table A3-7). It should be noted that this method does not account for additives that may increase or decrease digestibility.

TABLE A3-7: Approximate Digestible Energy (DE) for Selected Livestock and Data Sources

Animal Category	Digestible Energy %	Data Sources[1]
Goats	65	W. Whitmore, Manitoba Agriculture and Food
Laying Hens	80	S. Leeson, University of Guelph; D. Korver, University of Alberta
Broilers	80	S. Leeson, University of Guelph; D. Korver, University of Alberta
Turkeys	78	S. Leeson, University of Guelph
Swine	87	C.F. deLange, University of Guelph
Feeding on Grain Diet		
Dairy Cattle	80	N. Odongo, University of Guelph
Beef Cattle	80	C. Wand, Ontario Ministry of Agriculture and Food
Sheep	74	Weston (2002)
Horses	70	L. Warren, Colorado State University
Feeding on Roughage Diet		
Dairy Cattle	65	N. Odongo, University of Guelph
Beef Cattle	60	C. Wand, Ontario Ministry of Agriculture and Food
Sheep	65	W. Whitmore, Manitoba Agriculture and Food
Horses	60	L. Warren, Colorado State University

Note:

1 Expert consultations are referred to in Marinier et al. (2004).

Manure Ash Content (ASH)

The manure ash content is required to obtain an estimate of the organic portion of the manure. Table A3-8 contains the recommended values obtained for this parameter from various sources.

TABLE A3-8: Manure Ash Content for Selected Livestock and Data Sources

Animal Category	Ash %	Data Sources[1]
Cattle	8	IPCC (2000)
Sheep	8	IPCC (2000)
Goats	8	IPCC (2000)
Horses	4	IPCC (2000)
Laying Hens	10	S. Leeson, University of Guelph; D. Korver, University of Alberta
Broilers	7	S. Leeson, University of Guelph; D. Korver, University of Alberta
Turkeys	5	D. Spratt, Ontario Ministry of Agriculture and Food
Swine	5	C.F. Delange, University of Guelph

Note:

1 Expert consultations are referred to in Marinier et al. (2004).

Dry Matter Intake (DMI)

Ranges for DMI were determined through consultation with experts and published values (Table A3-9). Dairy cattle in Canada typically produce approximately 25 kg of milk per head per day (CDC, 2003). DMI is typically greater for lactating cows than for other cattle, because of the energy required for lactation. In general, cattle on a cow-calf farm will be consuming a lower digestible forage-based diet, while cattle on a feeder farm will be consuming a higher digestible grain-based diet. DMI will depend on the type of diet, the genotype of the cattle, the stage of lactation, and the time of year.

Swine represent one of the largest livestock industries in Canada, with approximately 14 million hogs on farms in 2003 (Statistics Canada, 2004c). Swine are kept inside confinement facilities and are fed a highly digestible grain-based ration. Swine rations vary across the country, with swine in eastern Canada consuming corn/soybean-based rations, while diets in western Canada generally include barley.

The goat industry in Canada is relatively small compared with the other livestock industries. There are also very few data available on goats. Nevertheless, DMI, DE, and ASH values were obtained using NRC (1981), AFRC (1998), and consultation with experts.

Poultry in Canada consists primarily of broiler chickens, laying hens, and turkeys. The breeding stock for turkeys represents only approximately 4% of the population (CTMA, 2004); thus, the values here are representative of the market livestock alone.

VS Calculation and Error Assessment

Using the values for DMI, DE, and ASH, VS was calculated for each livestock category by Marinier et al. (2004). A Monte Carlo simulation was performed using Crystal Ball (Decisioneering Inc., 2000), whereby a probability distribution was assigned to each of the inputs: DMI, DE, and ASH. Equation A3-7 was calculated 10 000 times using inputs within the assigned distributions, to arrive at the mean VS and 95% confidence interval (Table A3-10).

TABLE A3-9: Dry Matter Intake for Selected Livestock

Animal Category	Dry Matter Intake *kg/head per day*	Data Sources[1]
Dairy Cattle		
Cows	12.7–31.7	NRC (2001)
Replacement Heifers	6.9–13.8	NRC (2001)
Calves	4.1–6.2	NRC (2001)
Bulls	9–17	N. Odongo, University of Guelph
Beef Cattle		
Cows	11–14	NRC (2001)
Bulls	18–20	NRC (2001)
Replacement Heifers	7–11	NRC (2001)
Slaughter Heifers	7–11	NRC (2001)
Steers	7–11	NRC (2001)
Calves	4–6[2]	NRC (2001)
Sheep and Lambs		
Ewes	1.2–2.8	NRC (1985)
Rams	2.1–3.0	Statistics Canada (2004b); W. Whitmore, Manitoba Agriculture and Food
Replacement Lambs	1.2–1.5	NRC (1985)
Market Lambs	1.3–1.6	NRC (1985)
Horses		
Mature Idle Horses	7.4 –11	NRC (1989); L. Warren, Colorado State University
Mature Working Horses	7.4–13.7	NRC (1989); L. Warren, Colorado State University
Weanlings	3.6–6.3	NRC (1989)
Swine		
Starters (5–20 kg)	0.15–0.63[3]	M. Nyachoti, University of Manitoba; C. Pomar, Agriculture and Agri-Food Canada
Growers (20–60 kg)	1.4–2.1	J. Patience, Prairie Swine Centre
Finishers (60–110 kg)	2.1–3.3[3]	M. Nyachoti, University of Manitoba; C. Pomar, Agriculture and Agri-Food Canada
Sows	2.3–6.4	NRC (1998); M. Nyachoti, University of Manitoba
Boars	2.0–2.5	NRC (1998); M. Nyachoti, University of Manitoba
Goats		
Does	1.2–2.8	NRC (1981)
Bucks	1.4–2.3	CRAAQ (1999)
Kids	1.4	CRAAQ (1999)
Poultry		
Laying Hens	0.072–0.11	S. Leeson, University of Guelph; D. Korver, University of Alberta
Broilers	0.085–0.088	S. Leeson, University of Guelph; D. Korver, University of Alberta
Turkeys	0.23–0.53	Hybrid Turkeys (2001)

Notes:

1 Expert consultations are referred to in Marinier et al. (2004).

2 DMI for bulls and calves was calculated as 1.8% body weight. The weight ranges used were 1000–1090 kg for bulls and 218–340 kg for calves (C. Wand, Beef and Sheep Specialist, Ontario Ministry of Agriculture and Food).

3 Calculated as 3.5% of body weight (20 kg).

TABLE A3-10: Mean VS and Associated 95% Confidence Interval Expressed as a Percentage of the Mean for Each Livestock Category in Each Province

	Mean VS (and associated 95% confidence interval) *kg/head per day*									
Province	**BC**	**AB**	**SK**	**MB**	**ON**	**QC**	**NB**	**NS**	**PE**	**NL**
Dairy Cattle										
Cows	5.7 (45)	5.7 (45)	5.7 (45)	5.7 (45)	5.7 (45)	6.1 (44)	5.7 (45)	5.7 (45)	5.7 (45)	5.7 (45)
Bulls	4.1 (32)	3.9 (32)	3.8 (32)	3.9 (32)	4.1 (32)	3.9 (32)	4.2 (31)	4.2 (31)	4.2 (31)	4.2 (31)
Replacement Heifers	3.2 (35)	3.1 (35)	3.0 (35)	3.1 (35)	3.2 (35)	3.1 (35)	3.3 (35)	3.3 (35)	3.3 (35)	3.3 (35)
Calves	1.4 (24)	1.3 (23)	1.3 (23)	1.4 (24)	1.4 (24)	1.5 (24)	1.5 (23)	1.5 (23)	1.5 (23)	1.5 (23)
Beef Cattle										
Cows	4.6 (13)	4.5 (13)	4.5 (13)	4.5 (13)	4.6 (13)	4.6 (13)	4.6 (13)	4.6 (13)	4.6 (13)	4.6 (13)
Bulls	6.6 (8)	6.6 (8)	6.5 (8)	6.5 (8)	7.0 (8)	6.8 (8)	7.0 (8)	7.0 (8)	7.0 (8)	6.8 (8)
Replacement Heifers	3.2 (23)	3.1 (23)	3.2 (23)	3.1 (23)	3.2 (23)	3.1 (23)	3.1 (23)	3.1 (23)	3.1 (23)	3.2 (23)
Slaughter Heifers	2.7 (23)	2.6 (23)	2.8 (23)	2.8 (23)	2.6 (23)	2.6 (23)	3.0 (23)	3.0 (23)	3.0 (23)	2.8 (23)
Steers	2.7 (23)	2.6 (23)	2.8 (23)	2.8 (23)	2.6 (23)	2.6 (23)	3.0 (23)	3.0 (23)	3.0 (23)	2.8 (23)
Calves	1.5 (22)	1.4 (21)	1.2 (24)	1.3 (23)	1.1 (24)	1.0 (26)	1.4 (23)	1.4 (23)	1.4 (23)	1.6 (21)
Sheep										
Ewes	0.6 (42)	0.62 (42)	0.6 (42)	0.62 (42)	0.6 (41)	0.6 (41)	0.6 (42)	0.6 (42)	0.6 (42)	0.6 (41)
Rams	0.8 (20)	0.8 (20)	0.8 (20)	0.8 (20)	0.8 (20)	0.8 (20)	0.8 (20)	0.8 (20)	0.8 (20)	0.8 (20)
Breeding Lambs	0.4 (20)	0.4 (20)	0.4 (20)	0.4 (19)	0.4 (19)	0.4 (20)	0.4 (19)	0.4 (19)	0.4 (19)	0.4 (19)
Market Lambs	0.5 (13)	0.5 (13)	0.4 (15)	0.5 (13)	0.5 (13)	0.4 (15)	0.5 (13)	0.4 (14)	0.5 (13)	0.5 (13)
Horses										
Mature Horses	3.2 (15)	3.2 (15)	3.3 (16)	3.2 (15)	3.2 (15)	3.1 (16)	3.2 (15)	3.2 (15)	3.2 (16)	3.2 (15)
Swine										
Starters (5–20 kg)	0.05 (80)	0.05 (80)	0.05 (80)	0.04 (100)	0.05 (80)	0.05 (80)	0.05 (80)	0.05 (80)	0.05 (80)	0.05 (80)
Growers (20–60 kg)	0.23 (35)	0.23 (35)	0.23 (35)	0.20 (40)	0.22 (36)	0.22 (36)	0.23 (35)	0.23 (35)	0.23 (35)	0.23 (35)
Finishers (60–110 kg)	0.36 (33)	0.36 (33)	0.36 (33)	0.31 (39)	0.34 (35)	0.34 (35)	0.36 (33)	0.36 (33)	0.36 (33)	0.36 (33)
Sows	0.57 (53)	0.57 (53)	0.57 (53)	0.49 (57)	0.54 (56)	0.54 (56)	0.57 (53)	0.57 (53)	0.57 (53)	0.57 (53)
Boars	0.29 (27)	0.29 (27)	0.29 (27)	0.25 (32)	0.28 (29)	0.28 (29)	0.29 (27)	0.29 (27)	0.29 (27)	0.29 (27)
Goats										
All Goats	0.64 (41)	0.64 (41)	0.64 (41)	0.64 (41)	0.64 (41)	0.64 (41)	0.64 (41)	0.64 (41)	0.64 (41)	0.64 (41)
Poultry										
Laying Hens	0.02 (26)	0.02 (26)	0.02 (26)	0.02 (26)	0.02 (26)	0.02 (26)	0.02 (26)	0.02 (26)	0.02 (26)	0.02 (26)
Broilers	0.02 (16)	0.02 (16)	0.02 (16)	0.02 (16)	0.02 (16)	0.02 (16)	0.02 (16)	0.02 (16)	0.02 (16)	0.02 (16)
Turkeys	0.06 (28)	0.06 (28)	0.06 (28)	0.06 (28)	0.06 (28)	0.06 (28)	0.06 (28)	0.06 (28)	0.06 (28)	0.06 (28)

Source: Marinier et al. (2004)

Maximum CH_4 Producing Potential (B_o)

Maximum CH_4 producing potential (B_o) has been determined from several studies examining anaerobic digestion (Hashimoto et al., 1981; Safely et al., 1992). B_o is defined as the maximum volume of CH_4 that can be produced from 1 kg of VS loaded into a manure management system and is expressed in m^3/kg VS loaded. Because it is a measure of the maximum CH_4 production, B_o is not affected by the temperature at which manure is digested (Hashimoto et al., 1981). Factors that affect B_o include diet, age of manure, amount of foreign material, and species. Swine manure has the highest CH_4 producing potential, followed by poultry, beef cattle, and dairy cattle. Very little research has been done to determine the B_o of horses, and no research could be found on sheep or goat manure. Because of a lack of available data in Canada, the IPCC default B_o values are used (Table A3-11).

TABLE A3-11: Values of Maximum CH_4 Producing Potential (B_o) for Various Livestock Types

Animal Category	Maximum CH_4 Producing Potential (B_o) *m^3/kg VS*	Most Likely Value of B_o *m^3/kg VS*	Data Source
Dairy Cattle	0.1–0.24	0.24	IPCC (2000)
Beef Cattle	0.17–0.33	0.17	IPCC (2000)
Sheep	0.19–0.36	0.19	IPCC (2000)
Goats[1]	0.15–0.19	0.17	IPCC (2000)
Horses[1]	0.3–0.36	0.33	IPCC (2000)
Swine	0.32–0.49	0.45	IPCC (2000)
Poultry	0.24–0.36	0.32	IPCC (2000)

Note:

1 Range based on most likely value ± 10%, as no literature values were found.

Methane Conversion Factor (MCF)

MCF (Table A3-12) is the proportion of B_o that is realized and is affected by the storage system and climate region. Canada is considered a "cool climate," whereby the average annual air temperature is below 15°C.

TABLE A3-12: Methane Conversion Factor (MCF) for Each Manure Management System

Manure Management System	MCF *%*	Most Likely Value *%*	Data Source
Liquid/Slurry	3–39	39	IPCC (2000)
Solid	0–1.6	1	IPCC (2000)
Pasture and Paddock[1]	0.9–1.1	1	IPCC (2000)

Note:

1 Range based on most likely value ± 10%, as no literature values were found.

Manure System Distribution Factor (MS)

The manure system distribution factor (MS) is the proportional distribution of AWMS within a given area. There has not been any scientific literature published on the distribution of manure management systems in Canada. While every provincial department of agriculture has information about manure management practices, no information could be found on the distribution of these practices within the provinces.

In 2001, Statistics Canada conducted a survey entitled "Farm Environmental Management Survey" (FEMS). The results from FEMS were published in Statistics Canada (2003d). The report has a few limitations. First, only manure managed on beef cattle, dairy cattle, and swine farms was included in the survey results. Second, manure management systems were split into "liquid" and "solid/semi-solid" categories. Due to these limitations, a new survey was conducted, and manure system distributions by major domestic animals are listed (see Table A3-13) (Marinier et al., 2004). For beef, dairy, swine, and poultry, these values were calculated using a weighted average based on population. For horses, sheep, and goats, these values are a non-weighted average based on the survey responses.

TABLE A3-13: **Percentage of Manure Handled by AWMS[1,2]**

Animal Category	Liquid Systems	Solid Storage and Drylot	Pasture and Paddock	Other Systems
Non-Dairy Cattle	1	47	48	4
Dairy Cattle	42	40	18	0
Poultry	10	88	2	0
Sheep and Lambs	0	38	62	0
Swine	96	3	0	1
Other (Goats, Horses, and Buffaloes)	0	42	58	0

Notes:

1 Data source: Marinier et al., (2004).

2 These values are used for N_p in Equation A3-10 below (N_2O emissions).

A3.1.3 NITROUS OXIDE EMISSIONS FROM MANURE MANAGEMENT

The IPCC Tier 1 methodology is used to estimate N_2O emissions from AWMS. The IPCC methodology is based on the quantity of manure nitrogen produced by domestic animals and the methods of AWMS. Emission estimates of N_2O from AWMS, excluding those from manure in pasture and paddock systems, are calculated using Equation A3-9. (Note that N_2O emissions from the manure on pasture and paddock are covered under Agricultural Soils.)

N_2O emissions from animal production systems from different types of livestock in Canada are estimated using Equation A3-9. Three factors are required for estimating emissions of N_2O resulting from manure management: (1) nitrogen excretion rates for various animal types and categories, (2) types of AWMS, and (3) emission factors associated with each manure management system. AWMS in Canada are composed of liquid systems, solid storage and drylot, pasture and paddock, and other systems.

Equation A3-9:

$$N_2O_{AWMS} = \left(N_T \times NE \times N_A\right) \times \frac{44}{28}$$

where:

N_2O_{AWMS} = N_2O emissions for each specific AWMS

N_T = population for each specific animal category (by province)
Refer to "Methane Emissions from Enteric Fermentation" for livestock population data sources and calculations

NE = nitrogen excretion rate for each animal category
Refer to Table A3-14

N_A = fraction of nitrogen available for N_2O emissions from manure management for specific AWMS
Refer to Equation A3-9a

44/28 = the ratio of the molecular weight of N_2O to the molecular weight of N_2

Equation A3-9a:

$$N_A = N_P \times N_L$$

where:

N_P = percentage of nitrogen produced by AWMS (%)
Refer to Table A3-13

N_L = percentage of manure nitrogen excreted that is lost as N_2O (emission factors for specific AWMS)
Refer to Table A3-15

The N_2O emissions are estimated on a provincial basis. The estimates are updated on an annual basis. However, the estimates for horse, goat, and buffalo animal categories depend on Census of Agriculture data and are therefore revised only every five years (last year of revision: 2001).

A3.1.3.1 Nitrogen Excretion Rates for Various Domestic Animals

The Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1997) provide default rates of nitrogen excretion for various domestic animal categories for North America. There have been very few comprehensive, scientific studies on the rate of nitrogen excretion for various domestic animals in Canada. However, the U.S.-based American Society of Agricultural Engineering (ASAE, 1999) has published average rates of nitrogen excretion. These values, listed in Table A3-14, are considered to be more representatives of Canadian conditions than IPCC default values and have therefore been adopted.

TABLE A3-14: Nitrogen Excretion Rate for Each Specific Animal Category

Animal Category	Nitrogen Excretion (NE) *kg N/head per year*
Non-Dairy Cattle	44.7
Dairy Cattle	105.2
Poultry	0.36
Sheep and Lambs	4.1
Swine	11.6
Other (Goats, Horses, and Buffaloes)	49.3

Source: ASAE (1999).

The quantity of nitrogen excretion is estimated using the average rate of nitrogen excretion for a specific animal category multiplied by the respective animal population.

A3.1.3.2 Animal Waste Management Systems

In Canada, the major types of AWMS include liquid, drylot, pasture and paddock, and others. However, there is no formal tracking of AWMS, by animal category, in place at this time. Therefore, the percentages of manure handled in specific AWMS, as presented in Table A3-13, are based on expert opinion (Marinier et al., 2004).

A3.1.3.3 Emission Factors Associated with Animal Waste Management Systems

It is known that the type of AWMS has a significant impact on N_2O emissions. Less aerated systems, such as liquid systems, generate little N_2O, while drylots or manure on pasture and paddock produce more. However, there is little scientific information in Canada specifying amounts of N_2O emissions associated with manure management systems. Therefore, IPCC default emission factors, as listed in Table A3-15, are used for emission estimates.

TABLE A3-15: Percentage of Manure Nitrogen Lost as N_2O-N for Specific AWMS (N_L)

Animal Category	Liquid Systems	Solid Storage and Drylot	Pasture and Paddock	Other Systems
Non-Dairy Cattle	0.1	2.0	2.0	0.5
Dairy Cattle	0.1	2.0	2.0	0.5
Poultry	0.1	2.0	2.0	0.5
Sheep and Lambs	0.1	2.0	2.0	0.5
Swine	0.1	2.0	2.0	0.5
Other (Goats, Horses, and Buffaloes)	0.1	2.0	2.0	0.5

A3.1.4 NITROUS OXIDE EMISSIONS FROM AGRICULTURAL SOILS

A3.1.4.1 Direct Nitrous Oxide Emissions

Synthetic Nitrogen Fertilizers

- **Methodology**

The IPCC Tier 1 methodology is used to estimate N_2O emissions from synthetic fertilizer application on agricultural soils. Equation A3-10 is used to estimate N_2O emissions by province and for the country as a whole:

Equation A3-10:

$$N_2O_{SFN} = \left(SF_T * F_{SFN} * EF_T\right) * \frac{44}{28}$$

where:

N_2O_{SFN} = emissions from synthetic fertilizer nitrogen

SF_T = total synthetic fertilizer consumption (kg N/year)

F_{SFN} = fraction of synthetic fertilizer nitrogen available for nitrification/denitrification processes
Refer to Equation A3-10a

Equation A3-10a:

$$F_{SFN} = 1 - Frac_{GASF}$$

where:

$Frac_{GASF}$ = fraction of synthetic fertilizer nitrogen applied to soil that volatilizes as NH_3 and NO_x
= *0.1 kg (NH_3-N + NO_x-N)/kg N (IPCC, 1997)*

EF_T = emission factor (IPCC default)
= 0.0125 kg N_2O-N/kg N (IPCC/OECD/IEA, 1997)

44/28 = the ratio of the molecular weight of N_2O to the molecular weight of N_2

Data Source

The Farm Input Markets Unit of the Farm Income and Adaptation Policy Directorate of Agriculture and Agri-Food Canada produces an annual publication titled "Canadian Fertilizer Consumption, Shipments and Trade" (Korol, 2003). This material is also available on the web at: www.agr.ca/policy/cdnfert/text.html. According to this information, the most reliable sources for fertilizer consumption are the regional fertilizer associations that conduct surveys of all the principal companies engaged in fertilizer retailing at the provincial level.

Manure Applied as Fertilizer

Methodology

Emissions of N_2O in this section represent the N_2O produced from the application of manure from drylot, liquid, and other waste management systems as fertilizer on agricultural soils. The IPCC Tier 1 methodology is used to estimate N_2O emissions from manure applied as fertilizer. The IPCC methodology is based on the quantity of manure nitrogen produced by domestic animals and the methods of AWMS. N_2O emission estimates from this source, including all manure nitrogen produced from AWMS (excluding manure on pasture and paddock systems), are calculated using Equation A3-11:

Equation A3-11:

$$N_2O_{MAF} = \left(N_{EX} * F_A * EF_1\right) * \frac{44}{28}$$

where:

N_2O_{MAF} = N_2O emissions from animal manure applied as fertilizers

N_{EX} = total nitrogen from AWMS excluding manure on pasture, range, and paddock
Refer to Equation A3-11a

F_A = fraction of nitrogen that is available for nitrification/denitrification processes due to animal waste applied as fertilizers
Refer to Equation A3-11b

Equation A3-11a:

$$N_{EX} = \Sigma N_{AWMS} - \Sigma N_{PR\&P}$$

Assuming that all nitrogen produced from all AWMS excluding pasture, range, and paddock is applied as fertilizer.

where:

ΣN_{AWMS} = sum of nitrogen from the following AWMS:
- liquid systems;
- solid storage and drylot;
- pasture and paddock;
- other systems

$\Sigma N_{PR\&P}$ = sum of nitrogen from pasture and paddock system

Refer to Nitrous Oxide Emissions from Manure Management, Section A3.1.2, for nitrogen from AWMS and pasture range and paddock system for data sources and calculation of ΣN_{AWMS} and $\Sigma N_{PR\&P}$

Equation A3-11b:

$$F_A = 1 - Frac_{GASM}$$

where:

$Frac_{GASM}$ = fraction of livestock nitrogen excreted that is volatilized as NH_3 and NO_x
= *0.2 kg (NH_3-N + NO_x-N)/kg N (IPCC/OECD/IEA, 1997)*

EF_1 = emission factors for manure nitrogen applied as fertilizers
= *0.0125 kg (N_2O-N)/kg N (IPCC/OECD/IEA, 1997)*

44/28 = the ratio of the molecular weight of N_2O to the molecular weight of N_2

Biological Nitrogen Fixation

Methodology

The IPCC Tier 1 methodology is used to estimate N_2O emissions from nitrogen-fixing crops. Equation A3-12 is used to estimate provincial N_2O emissions from nitrogen-fixing crops:

Equation A3-12:

$$N_2O_{BNF} = \left(N_{FC} * F_N * EF_T\right) * \frac{44}{28}$$

where:

N_2O_{BNF} = N_2O emissions from nitrogen-fixing crops

N_{FC} = amount of nitrogen produced from nitrogen-fixing crops

Refer to Equation A3-12a

Equation A3-12a:

$$N_{FC} = \Sigma\ (2 * (C_T * DMF_T))$$

Assuming the mass of nitrogen-fixing crops is twice (2:1) the mass of edible portions (except for the mass of alfalfa, 1:1). The mass of nitrogen-fixing crops (alfalfa) is estimated to be 60% of the mass of tame hay produced.

where:

C_T = specific type of nitrogen-fixing crop produced

DMF_T = specific dry matter fraction

Refer to Table A3-16.

F_N = fraction of nitrogen content from dry mass of crops produced

= 0.03 kg N/kg dry mass (IPCC/OECD/IEA, 1997)

Assuming dry mass nitrogen content is constant for all nitrogen-fixing crops

EF_T = emission factor

= 0.0125 kg N_2O-N/kg N (IPCC/OECD/IEA, 1997)

44/28 = the ratio of the molecular weight of N_2O to the molecular weight of N_2

TABLE A3-16: Dry Matter Fraction (DMF_T) of Leguminous Crops

Specific Crop Types	Dry Matter Fraction DMF_T
Peas	0.86
Beans	0.86
Soya	0.86
Lentils	0.86
All Others	0.86

Source: Expert opinion (R. Desjardins, Agriculture and Agri-Food Canada; C. Liang, Environment Canada).

Data Source

Statistics Canada collects annual field crop data and publishes "Table 1, November estimate of the 2003 production of principal field crops, Canada" (Statistics Canada, 2003c). Non-nitrogen-fixing crops include wheat, barley, corn/maize, oats, rye, mixed grains, flax seed, canola, buckwheat, mustard seed, sunflower seed, canary seeds, fodder corn, and sugar beets. Nitrogen-fixing crops include dry peas, soybean, dry white beans, coloured beans, chick peas, and lentils. Figures for tame hay are also included.

Crop Residues

Methodology

The decomposition of crop residues left on fields results in N_2O emissions into the atmosphere. The IPCC Tier 1 methodology is used to estimate N_2O emissions from crop residues. Equation A3-13 below is used to estimate provincial emissions of N_2O from crop residues:

Equation A3-13:

$$N_2O_{CR} = 2 * \left\{ \begin{matrix} [(\Sigma C_{TCR} * F_{NFC}) + (\Sigma\ C_{TNF} * F_N)] \\ * (1-F_B) * (1-F_R) * EF_1 \end{matrix} \right\} * \frac{44}{28}$$

where:

N_2O_{CR} = N_2O emissions from crop residues

ΣC_{TCR} = sum of all non-nitrogen-fixing crops

Refer to Equation A3-13a

ΣC_{TNF} = sum of all nitrogen-fixing crops

Refer to Equation A3-13b

Equation A3-13a:

$$\Sigma C_{TCR} = (C_{TCR} * DMF_T)$$

where:

C_{TCR} = non-nitrogen-fixing crop produced

Non-nitrogen-fixing crops include wheat, barley, corn/maize, oats, rye, mixed grains, flax seed, canola, buckwheat, mustard seed, sunflower seed, canary seeds, fodder corn, and sugar beets.

DMF_T = specific dry matter fraction

Refer to Table A3-17

Equation A3-13b:

$$\Sigma C_{TNF} = (C_{TNF} * DMF_T)$$

where:

C_{TNF} = nitrogen-fixing crop produced
Nitrogen-fixing crops include dry peas, soybean, dry white beans, coloured beans, chick peas, and lentils. Tame hay is also reported, but not used here.

DMF_T = specific dry matter fraction
Refer to Table A3-17

F_{NFC} = 0.015 kg N/kg dry mass (IPCC/OECD/IEA, 1997)
Assuming constant fraction of nitrogen in non-nitrogen-fixing crops

F_N = 0.03 kg N/kg dry mass (IPCC/OECD/IEA, 1997)
Assuming constant fraction of nitrogen in nitrogen-fixing crops

F_B = fraction of crop residues that are burned
= *0 kg N/kg dry mass*
Assumed to be negligible in Canada

F_R = fraction of crop mass removed from fields = 45%
Assuming that 55% of crop mass remains in fields as crop residues

EF_1 = emission factor
= *0.0125 kg N_2O-N/kg N (IPCC/OECD/IEA, 1997)*

44/28 = the ratio of the molecular weight of N_2O to the molecular weight of N_2

TABLE A3-17: Dry Matter Fraction (DMF_T) of Crops

Specific Crop Types	Dry Matter Fraction DMF_T
Wheat	0.86[1]
Barley	0.86[1]
Maize	0.86[2]
Oats	0.86[2]
Rye	0.86[2]
Peas	0.86[2]
Beans	0.86[2]
Soya	0.86[2]
Fodder Corn	0.30[2]
Lentils	0.86[2]
Sugar Beets	0.20[2]
All Others	0.86[2]

Sources:

1 IPCC/OECD/IEA (1997).

2 Expert opinion (R. Desjardins, Agriculture and Agri-Food Canada; C. Liang, Environment Canada).

- **Data Source**

Statistics Canada collects annual field crop data and publishes "Table 1, November estimate of the 2003 production of principal field crops, Canada" (Statistics Canada, 2003c). Non-nitrogen-fixing crops include wheat, barley, corn/maize, oats, rye, mixed grains, flax seed, canola, buckwheat, mustard seed, sunflower seed, canary seeds, fodder corn, and sugar beets. Nitrogen-fixing crops include dry peas, soybean, dry white beans, coloured beans, chick peas, and lentils.

Cultivation of Histosols

- **Methodology**

Cultivation of organic soil (histosols) for annual crop production produces N_2O. The IPCC Tier 1 methodology is used to estimate N_2O emissions from cultivated organic soils. N_2O emissions from cultivation of histosols are calculated as shown in Equation A3-14:

Equation A3-14:

$$N_2O_H = A_{OS} * EF * \frac{44}{28}$$

where:

N_2O_H = N_2O emissions from histosols

A_{OS} = total area of cultivated organic soils

EF = IPCC default emission factor
= 8 kg N_2O-N/ha per year (IPCC, 2000)

44/28 = the ratio of the molecular weight of N_2O to the molecular weight of N_2

- **Data Source**

Areas of cultivated histosols at a provincial level are not covered in the Census of Agriculture, which is collected regularly at five-year intervals by Statistics Canada. In the absence of these data, consultations with numerous soil and crop specialists across Canada have been made. Based on these consultations, the total area of cultivated organic soils in Canada is 15 654 ha (G. Padbury and G. Patterson, personal communication) and is assumed to be constant from 1990 to 2003. This area is believed to represent a close approximation of the actual area.

Manure on Pasture and Paddock from Grazing Animals

- **Methodology**

The IPCC Tier 1 default methodology is used to estimate N_2O emissions from manure on pasture and paddock from grazing animals. The IPCC methodology is based on the quantity of manure nitrogen produced by domestic animals on pasture and paddock. N_2O emissions from manure on pasture and paddock are calculated using Equation A3-15. Note that N_2O emissions from manure on pasture and paddock are reported under Agricultural Soils, not under Manure Management.

Equation A3-15:

$$N_2O_{MPP} = \Sigma_{Types}\left(N_T * NE * N_A\right) * \frac{44}{28}$$

where:

N_2O_{MPP} = N_2O emissions from manure on pasture and paddock from grazing animals

N_T = animal population (by province)
Refer to "Methane Emissions from Enteric Fermentation" for livestock population data sources and calculations

NE = nitrogen excretion rate for each animal category
Refer to Table A3-14

N_A = fraction of nitrogen available for N_2O emissions from manure on pasture and paddock
Refer to Equation A3-15a

Equation A3-15a:

$$N_A = N_P * N_L$$

where:

N_P = percentage of nitrogen produced on pasture and paddock by AWMS (%)
Refer to Table A3-15

N_L = fraction of manure nitrogen excreted that is lost as N_2O-N
= 0.02 kg N_2O-N/kg N (IPCC/OECD/IEA, 1997)

44/28 = the ratio of the molecular weight of N_2O to the molecular weight of N_2

A3.1.4.2 Indirect Nitrous Oxide Emissions

Volatilization and Redeposition of Nitrogen

- **Methodology**

The IPCC Tier 1 methodology is used to estimate indirect N_2O emissions due to volatilization and redeposition of fertilizer and manure nitrogen applied to agricultural soils. The emission calculation is shown in Equation A3-16:

Equation A3-16:

$$N_2O_{VD} = \left[\left(SF_P * EF_{SF}\right) + \left(N_{LS} * EF_{LS}\right)\right] EF_{VD} * \frac{44}{28}$$

where:

N_2O_{VD} = indirect N_2O emissions due to volatilization and redeposition

SF_P = provincial synthetic fertilizer consumption (all fertilizer types)
Refer to Equation A3-16a.

Equation A3-16a:

$$SF_P = \Sigma_{Types}\, SF_T$$

where:

SF_T = specific synthetic fertilizer consumption (kg N/year)
Refer to "Direct Nitrous Oxide Emissions — Synthetic Nitrogen Fertilizers" methodology for calculation and data source

N_{LS} = total nitrogen from livestock excretion
Refer to Equation A3-16b

Equation A3-16b:

$$N_{LS} = \sum_{All\ Animal\ Types} (N_T * NE)$$

where:

N_T = animal population
Refer to "Methane Emissions from Enteric Fermentation" methodology for calculation and data source

NE = nitrogen excretion from each specific animal type
Refer to "Nitrous Oxide Emissions from Manure Management" methodology for calculation and data source

EF_{SF} = fraction of synthetic fertilizer nitrogen applied to soils that volatizes as NH_3 and NO_x
= 0.1 kg (NH_3-N + NO_x-N)/kg N (IPCC/OECD/IEA, 1997)

EF_{LS} = fraction of excreted livestock nitrogen that is available for volatilization as NH_3 and NO_x
= 0.2 kg (NH_3-N + NO_x-N)/kg N (IPCC, 1997)

EF_{VD} = emission factor due to volatilization
= 0.01 kg N_2O-N/kg N (IPCC/OECD/IEA, 1997)

44/28 = the ratio of the molecular weight of N_2O to the molecular weight of N_2

Leaching, Runoff, and Erosion

Methodology

The IPCC Tier 1 methodology is used to estimate indirect N_2O emissions from leaching, runoff, and erosion of fertilizers or manure nitrogen applied to agricultural soils.

Equation A3-17:

$$N_2O_L = F_L * EF_L \left(SF_P + N_{LS} \right) \frac{44}{28}$$

where:

N_2O_L = indirect N_2O emissions due to leaching and runoff

F_L = fraction of nitrogen that is lost through leaching and runoff

= 0.15 kg N/kg of fertilizer- or manure-N

EF_L = leaching/runoff emission factor

= 0.025 kg N_2O-N/kg N (IPCC/OECD/IEA, 1997)

SF_P = specific provincial synthetic fertilizer consumption (all fertilizer types)
Refer to Equation A3-17a

Equation A3-17a:

$$SF_P = \Sigma_{Types}\ SF_T$$

where:

SF_T = specific synthetic fertilizer consumption
Refer to "Direct Nitrous Oxide Emissions — Synthetic Nitrogen Fertilizers" methodology for calculation and data source

N_{LS} = total nitrogen from livestock excretion
Refer to Equation A3-17b

Equation A3-17b:

$$N_{LS} = \Sigma_{Types}\ (N_T * NE)$$

where:

N_T = animal population
Refer to "Methane Emissions from Enteric Fermentation" methodology for calculation and data source

NE = nitrogen excretion from each specific animal category
Refer to "Nitrous Oxide Emissions from Manure Management" methodology for calculation and data source

44/28 = the ratio of the molecular weight of N_2O to the molecular weight of N_2

Fraction of Synthetic Fertilizer and Manure Nitrogen Leached

The IPCC Tier 1 methodology assumes that 30% of the nitrogen applied as synthetic fertilizer or manure is lost by leaching or runoff. This amount is then multiplied by 0.025 kg N_2O-N/kg leaching-runoff-N to obtain an emission estimate (IPCC/OECD/IEA, 1997).

In Canada, leaching losses of nitrogen vary widely among regions. High nitrogen inputs in humid conditions may lead to greater than 100 kg N/ha per year in some farming systems of southern British Columbia (Paul and Zebarth, 1997; Zebarth et al., 1998). Such losses, however, represent only a small fraction of Canadian agroecosystems. In Ontario, Goss and Goorahoo (1995) predicted leaching losses of 0–37 kg N/ha, accounting for 0–20% of nitrogen inputs from seed, feed, fertilizer, manure, animals, nitrogen fixation, and atmospheric deposition. Leaching losses in most of the prairie region may be smaller due to lower precipitation and lower nitrogen inputs. Based on a long-term experiment in central Alberta, Nyborg et al. (1995) suggested that leaching losses were minimal, and Chang and Janzen (1996) found no evidence of nitrogen leaching in non-irrigated, heavily manured plots, despite large accumulations of soil nitrate in the soil profile. In the Prairie provinces of western Canada, which account for more than 80% of fertilizer inputs and agricultural land in Canada, potential evaporation exceeds precipitation by a large margin (Reynolds et al., 1995). Leaching losses in Canada are probably lower than in many other countries with intensive agriculture. Thus, IPCC default leaching losses of 30% were reduced to 15% to reflect Canadian climatic conditions.

A3.2 METHODOLOGY FOR LAND USE, LAND-USE CHANGE AND FORESTRY

In the current submission, the LULUCF Sector of the inventory includes the GHG emissions/removals associated with managed lands and with land conversion to different uses. This annex contains information on how estimates are derived for the three major LULUCF components: Forest Land Remaining Forest Land, Cropland Remaining Cropland, and Land Conversion. Different approaches to the estimation of delayed emissions due to carbon storage in HWPs are briefly described, along with implications for Canada.

A3.2.1 FOREST LAND REMAINING FOREST LAND

A3.2.1.1 Data Sources

The primary source of forest data is Canada's Forest Inventory (CanFI, 2001), compiled by the Canadian Forest Service of NRCan from 57 forest inventories in Canadian provinces and territories. These source inventories vary in level of detail, coverage, and frequency of updates, and they lack common, quantitative standards. At the time of preparation of this GHG inventory, the most recent forest inventory information available for each province and territory was used, including:

- the areal extent of forest, both stocked and temporarily unstocked stands, for each of 12 forest regions;
- when available, the breakdown of the stocked forest areas in each forest region in five maturity classes: regeneration, immature, mature, overmature, and uneven-aged forest stands;
- for each forest region, the mean annual volume increment (MAI) from inventoried, timber-productive forest with access (Lowe et al., 1994: Table 16.17). MAI values are derived separately for mature stands, by forest region, site class, and predominant genus or forest type, and made available at the aggregated level by the Canadian Forest Service of NRCan; they take into account mortality and growth reduction due to non-stand-replacing disturbances, competition, and disease;
- data on silvicultural activities (volumes of industrial roundwood and fuelwood harvests; areas of clearcut harvests), obtained from the Compendium of Forestry Statistics maintained by the Canadian Council of Forest Ministers and made publicly available through the online National Forestry Database (CCFM, 2004). These data generally cover the period up to two or three years prior to the submission year; and
- maps of the boundaries of each spatial unit of the CanFI database, and a database of the extent of managed forests within each spatial unit.

In addition to CanFI information, the procedures used to estimate the area burned within the managed forests rely on a database of large (>200 ha) forest fires in Canada since 1990, developed and maintained by NRCan (Stocks et al., 2002).

Data on commodity production and trade are obtained from the Food and Agriculture Organization of the United Nations Forestry Database,[42] with the exception of market pulp data, which are provided directly by the Pulp and Paper Products Council (2004).

The amount of firewood collected is equal to the total domestic firewood consumption in Canada, as developed by Environment Canada for its 1995 CAC Inventory (Environment Canada, 1999) and reported in the Energy Sector of this inventory.

A3.2.1.2 General Approach and Methods

The methodology for estimating GHG emissions and removals on managed forest land is based on the approach developed in the IPCC guidelines (IPCC/OECD/IEA, 1997) and elaborated in the IPCC Good Practice Guidance report (IPCC, 2003: Chapter 3, Equations 3.2.4–3.2.9). Net removals or emissions are calculated as the difference between CO_2 uptake through forest tree growth and emissions resulting from commercial forest management (harvested roundwood, fuelwood[43] collection, and site preparation with prescribed burning) and domestic firewood collection (Figure A3-1). Due to their predominant role in the ecology and stand dynamics of Canadian forests, wildfires have also been included in the GHG balance of the managed forests. The current estimation methodology is limited to the aboveground biomass carbon pool.

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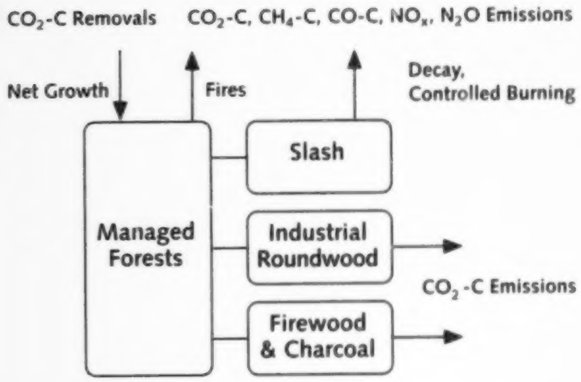
[42] See website: http://faostat.fao.org/faostat/colections?subset=forestry

[43] In Canada, fuelwood refers to the biomass consumed for industrial energy generation, and firewood to biomass used for residential heating.

FIGURE A3-1: Schematic Representation of Estimation Methodology for Aboveground Biomass Carbon Pool



Equation A3-18 represents the generic approach to calculating carbon sequestration in aboveground biomass. It combines Equations 3.2.4 and 3.2.5 of the Good Practice Guidance report (IPCC, 2003).

Equation A3-18:

$$C\ removals = A * MAI * BCEF * C_{fraction}$$

where:

C removals = carbon uptake (t C/year)
A = area of growing forest (ha)
MAI = mean annual volume increment (m^3/ha per year)
BCEF = biomass conversion/expansion factor (t dry mass/m^3 of merchantable wood)
$C_{fraction}$ = carbon fraction of biomass (0.5)

It is assumed that CO_2 removals due to aboveground biomass increment are occurring only in the stocked forest areas, with the exclusion of overmature stands, where the net accumulation of aboveground biomass is assumed to be zero. This has been labelled the "growing" forest. The area of "growing" forest is estimated annually, based on initial maturity class distribution of the managed forests, historic and current data on disturbances, and post-disturbance regeneration delays.

Because the average, long-term MAI values are highly aggregated, they do not reflect the dynamic response of carbon sequestration rates as a result of changes in forest age structure and composition. An MAI — briefly described in the section above on data sources — is applied to the area of "growing" forest, in combination with a biomass conversion/expansion factor (BCEF) derived from standing aboveground biomass at maturity. Both exclude the carbon sequestered in biomass that is shed prior to stand maturity and either decomposes or remains in the ecosystem as dead biomass or soil organic matter. Hence, this approach provides generally conservative estimates of carbon sequestration in the aboveground biomass of the managed forests. Table A3-18 presents the values used for the 2003 inventory year.

Urban tree growth is estimated at 0.05 t dry mass/ha per year over 1700 ha of non-built-up urban areas.

Carbon losses from the managed forests are contained in the industrial roundwood harvested, the decay or burning of post-harvest biomass residues (slash), the fuelwood and firewood collected, and the biomass burned in wildfires (Equation A3.19). The carbon content of biomass is always estimated as 0.5 by weight.

Equation A3-19:

$$C\ losses = C_{irw} + C_{residues} + C_{fuelwood} + C_{firewood} + C_{wildfires}$$

where:

C losses = carbon removed from managed forest ecosystems (t C/year)
C_{irw} = carbon contained in the industrial roundwood harvested (t)
$C_{residues}$ = carbon contained in the post-harvest residues or slash (t)
$C_{fuelwood}$ = carbon contained in the harvested fuelwood (t)
$C_{firewood}$ = carbon contained in residential firewood (t)
$C_{wildfires}$ = carbon emitted by wildfires as CO_2, CH_4, and CO (t)

The biomass removed in the industrial roundwood is estimated as green volumes multiplied by specific wood densities, plus bark biomass. The quantity of harvest residues is estimated as the difference between pre-harvest standing biomass and that removed in industrial roundwood, fuelwood, and firewood. In addition to carbon losses, clearcut harvest reduces the stocked forest area.

TABLE A3-18: Estimation of Carbon Sequestration in Aboveground Biomass, Managed Forests, 2003

Forest Regions	Area of Growing Forest	MAI	BCEF	Annual Biomass Increment	Annual Carbon Increment
	kha	*m³/ha per year*	*t dry mass/m³ green volume*	*kt/year*	*kt C*
Boreal — Predominantly Forest	80 333	1.562	0.8151	102 276	51 138
Boreal — Forest and Grassland	1 309	1.817	0.6204	1 475	738
Boreal — Forest and Barren	6 352	0.448	1.0527	2 996	1 498
Subalpine	8 585	2.106	0.7436	13 444	6 722
Montane	7 020	1.763	0.7436	9 203	4 602
Coast	4 622	2.309	0.6184	6 601	3 301
Columbia	2 136	2.108	0.7436	3 348	1 674
Deciduous	205	2.073	0.9745	414	207
Great Lakes – St. Lawrence	14 986	1.821	0.9745	26 592	13 296
Acadian	8 141	1.548	0.8226	10 366	5 183
Grassland	920	1.276	0.8615	1 011	506
Tundra	3 318	0.786	0.7168	1 870	935
Total Boreal	**91 313**	–	–	**1.190**[1]	**54 309**
Total Temperate	**46 614**	–	–	**1.523**[1]	**35 491**
Total Canada	**137 927**	–	–	**179 599**	**89 800**

Note:

[1] Units are t/ha per year.

Table A3-19 provides 2003 estimates of the gross carbon losses from managed forests.

TABLE A3-19: Carbon Losses from Managed Forests, 2003

Source Category	Carbon Losses
	kt
Industrial Roundwood Harvested	41 726
Fuelwood Harvested	932
Firewood Collected	9 088
Post-Harvest Residues (Slash) Decay and Burning	9 547
Wildfires	11 060
Total	**72 353**

In generic terms, the estimation of GHG emissions from wildfires can be represented by Equation A3-20.

Equation A3-20:

$$\uparrow GHG_i = \Sigma_j (A_{i,j} * FC_j * EF_{GHG}) * 1000$$

where:

$\uparrow GHG_i$ = emissions of GHGs due to wildfires in managed forests for year i (Gg)

$A_{i,j}$ = area of managed forest burned during year i in ecozone j[44] (ha)

FC_j = average fuel biomass consumed by wildfires in ecozone j (kt dry mass/ha)

EF_{GHG} = emission factor for each GHG (g/kg dry mass)

Previous reports had noted the interannual variability and important uncertainty with respect to the location of wildfires within or outside managed forests; activity data were then estimated based on reports of forest area burned in poorly defined "intensive protection zones." A new procedure, based on different data sources, was implemented in the determination of the area of managed forests burned in 1990–2003 by wildfires.

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[44] Ecozone: Upper-level division in the Canadian Ecological Stratification System. Marshall et al. (1999). See http://sis.agr.gc.ca/cansis/nsdb/ecostrat/intro.html

In the procedure, GIS analysis allowed improved assessment of the forest area burned in managed forests every year and compilation of the total area burned in managed forests by ecological zones, as opposed to administrative unit. The analysis used two distinct data sets. The reference spatial dataset consists of the boundaries of the 101 488 polygons (i.e., boundaries of this many spatial units) making up the CanFI, provided by the Canadian Forest Service (CanFI, 2001). Among other attributes, the total forest area and managed forest area are provided for each polygon, although the locations are not explicit within each unit. The second dataset consists of the polygons outlining all large (>200 ha) forest fires identified for the years 1990–1999,[45] updated to 2003 by the Canadian Forest Service (Northern Forestry Centre, 2005). In total, 3842 fire events are registered in the database.

A spatial intersection was applied to the two polygon layers (forest inventory and large forest fires), combining the attribute data for those regions that intersect, so that each portion of a fire event occurring in an inventory polygon was assigned the forest inventory information of that polygon, in this case the ratio between the area of managed forest and total forest. This ratio was used to determine the proportion of the total forest area burned that was managed. The area of managed forest burned was tallied for each fire event, in each ecozone. Figure A3-2 illustrates the intersection process.

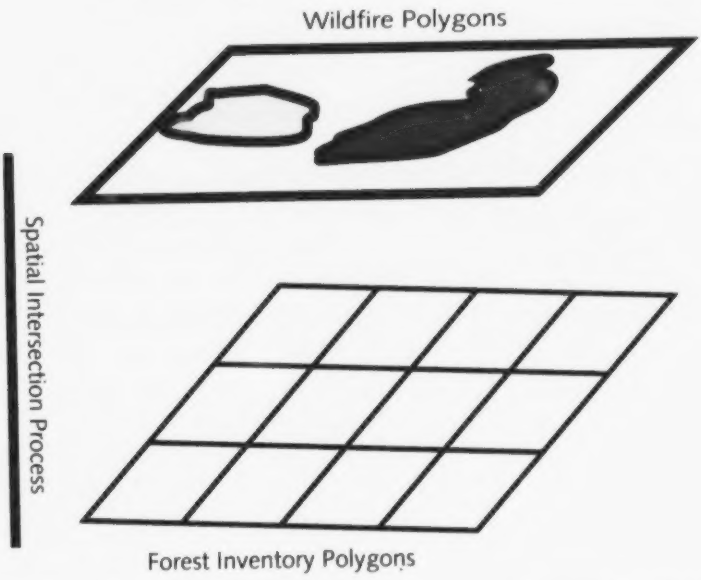
A published estimate of the average fuel biomass consumed per forest area burned, for each ecozone, was used to determine the total biomass consumption by wildfires in managed forests (Amiro et al., 2001). As in previous submissions, the factors used to estimate emissions of CO_2, CH_4, N_2O, and CO were derived from Taylor and Sherman (1996) (Table A3-20).

TABLE A3-20: Emission Factors for Wildfires

Gas	Emission Factors g/kg biomass oxidized
CO_2	1635
CH_4	3
N_2O	0.24
NO_x	1.75
CO	88

Source: Taylor and Sherman (1996).

FIGURE A3-2: Intersection of Two Information Layers: Forest Inventory Layer and Wildfire Events Layer



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[45] See website: http://fire.cfs.nrcan.gc.ca/research/climate_change/lfdb/lfdb_download_e.htm; see also Stocks et al. (2002).

In addition to direct GHG emissions, the impact of wildfires is accounted for indirectly as a reduction in the area of stocked forest. Average regeneration delays are applied to all historical disturbances, after which forest lands enter into the stocked forest category. Note that post-fire regeneration is not as well documented as post-harvest regeneration; in many cases, an average regeneration delay of 15 years had to be assumed.

The areas burned in managed forests resulting from the GIS analysis are considerably smaller than previously estimated, especially for the years 1994, 1995, and 1998. Table A3-21 shows the different results obtained with the former and the revised procedures for estimating managed forest area burned. Both fire location and size class distribution explain the variability found in the proportion of area burned located in managed forests. Figure A3-3 illustrates the variability of fire locations for the years 1994 and 1995. In both years, the total forest area burned was extremely large (6.2 Mha and 6.9 Mha, respectively). However, in 1994, only 35% of all fires were partly or entirely located in managed forests, compared with 66% of 1995 fires. As a result, in 1994, only 7% of the forest area burned was managed, while in 1995, the proportion reached 44%. In 1994, some very large fires (>200 000 ha) occurred completely outside the managed forests, explaining the large difference in outcome. The implementation of the GIS analysis resulted in a decrease of the corresponding GHG estimates.

TABLE A3-21: Forest Areas Burned, According to Different Data Sources and Estimation Procedures

Year	Revised Procedure: Spatial Overlay		Former Procedure: Forest Area Burned in Intensive Protection Zone	
	Total Forest Area Burned[1]	Forest Area Burned in Managed Forests	Total Forest Area Burned[1]	Forest Area Burned in the Intensive Protection Zone
1990	944 380	334 769	934 435	623 731
1991	1 603 923	827 781	1 584 730	1 160 266
1992	932 510	275 667	868 655	685 995
1993	2 149 462	761 879	1 967 701	1 707 601
1994	6 220 960	446 754	6 295 957	5 915 560
1995	6 943 520	3 075 418	7 095 103	6 023 341
1996	1 773 956	827 439	1 854 730	967 927
1997	588 449	328 159	630 700	262 777
1998	4 406 150	1 476 411	4 614 287	3 882 718
1999	1 739 637	645 817	1 624 611	1 238 781
2000	522 583	96 464	665 331	412 815
2001	570 540	257 687	601 425	512 399
2002	2 633 574	1 533 260	2 763 219e	1 746 579
2003	2 035 684	898 364	N/A	88 206

Notes:

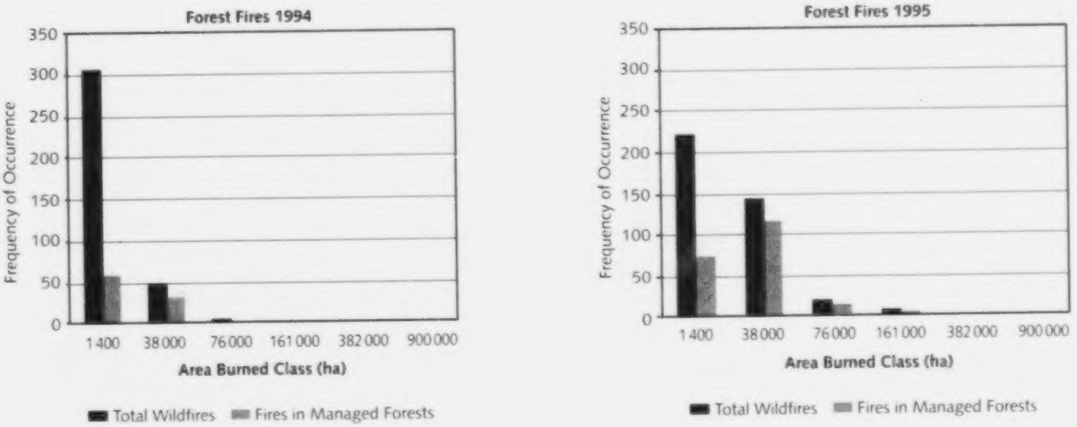
1 Total forest area burned is reported for both the former and current data sources. The minor discrepancies are attributable to the completely different data collection methods used for these two independent data sources. Overall, the data are deemed very consistent.

N/A = not available; e = estimated.

FIGURE A3-3: Locations of Wildfires Within or Outside Managed Forests, and the Corresponding Size Class Distribution of Fire Events, for the Years 1994 and 1995

1994 Wildfire Locations
Unmanaged Forest Fire
• Managed Forest Fire

1995 Wildfire Locations
Unmanaged Forest Fire
• Managed Forest Fire



A3.2.1.3 Uncertainties

The UNFCCC Reporting Guidelines identify four major sources of uncertainty, which all apply to the LULUCF Sector. These are definitions, methodology, activity data, and underlying scientific understanding. A major source of uncertainty is the lack of a spatial definition for the managed forests and the temporary values so far ascribed to their areas — i.e., 214 Mha in this report. Although the current estimate is more up to date, the probability is high that the forest area under direct human influence varies significantly from 214 Mha.

The main methodological source of uncertainty is the omission from the estimation methodology of important carbon pools such as forest soils, HWPs, coarse woody debris, and litter. The nature of this uncertainty is such that it is not possible at this time to conduct a quantitative uncertainty assessment on emission and removal estimates.

The second most important source of uncertainty associated with both methodology and data results from the use of highly aggregated, spatially coarse forest data, notably MAI, BCEF, and harvest areas. Their coarse spatial and temporal resolutions do not allow an accurate tracking of changes in forest sources and sinks. Disaggregated data do exist, but are not always available or comparable. In some instances, the required information is simply not documented, such as pre-disturbance stand characteristics and biomass utilization rates.

While the large (>200 ha) fires represent only a few percent of all fires, they usually account for most (more than 97%) of the area burned (Stocks et al., 2002). A comparison of total forest area burned in the large fire database with that reported in the national forestry database (CCFM, 2004) shows that estimates of total forest area burned are generally consistent. Although the general uncertainty with respect to the location of forest fires was reduced, the lack of completely explicit information on the boundaries of managed forests remains a source of error in the allocation of the area burned within managed forests. The uncertainty due to the use of a single fuel consumption factor for all forests burned was reduced, since a compilation of forest area burned by ecozone allowed the used of published, ecozone-specific consumption factors. Much uncertainty remains due to the omission of the effect of fire events on carbon pools other than aboveground biomass.

The impacts of all other stand-replacing disturbances are excluded from this assessment, although they do affect large areas. For example, entire tree populations may slowly die after repeated defoliation (e.g., by Spruce Budworm *Choristoneura fumiferana*) or following epidemics of wood-boring insects (e.g., Mountain Pine Beetle *Dendroctonus ponderosae*). However, the impact of these disturbances on aboveground biomass is less immediate than that of fires, since the carbon would primarily be transferred to the dead organic matter and soil carbon pools and oxidize over a period of several years or decades.

Work is under way to address these definitional and methodological deficiencies, the data gaps, and the scientific uncertainty, as described in Section 7.1.6 (Planned Improvements).

A3.2.2 CROPLAND REMAINING CROPLAND

A3.2.2.1 Cultivation of Mineral Soils

General Approach

The Century model was used to estimate the rate of SOC change in mineral soils in Canada. The Century model, developed by Parton et al. (1987), is a general model of the plant–soil system that simulates carbon dynamics in agricultural soils. After calibration, it can be used to simulate the diverse and myriad complexities that affect carbon fluxes in agricultural soils. This section briefly describes the method that Smith et al. (1997) developed for estimating fluxes or removals of CO_2 by mineral agricultural soils in Canada using the Century model.

The analysis was carried out on 180 1:1 000 000-scale Soil Landscape of Canada (SLC) polygons, representing 15% of the SLC polygons within Canada's agricultural area. The SLC polygons were stratified by soil zones and soil textural classes. For each sampled polygon, the Century model was run for one to five types of crop rotations under conventional tillage and no-tillage, providing that Census of Agriculture data showed that no-tillage was used on at least 5% of the polygon area.

Data Sources and Sampling Scheme

Soil data for the 1992 agriculturally designated SLC polygons were obtained from the Canadian Soil Inventory System (CanSIS) database. CanSIS is a hierarchical system of land inventory ranging from thousands of SLC polygons, the smallest and most detailed landscape areas with uniform coverage for all of Canada, to the ecodistricts, ecoregions, and, finally, the 15 ecozones of Canada. CanSIS provided soil data for the dominant soils (those that represent at least 40% of the polygon area) in each SLC polygon

SOC dynamics were estimated for the sample of 15% of the agricultural SLC polygons, stratified to obtain a proportional representation of each soil zone and textural class. A minimum of one polygon was sampled from each soil group, except for the Solonetzic soil group, which represents only 4% of the agricultural land and is poorly represented in Century. The number of polygons to be sampled within a textural class was calculated as the fraction of the total area the texture represented within a soil group multiplied by the number of polygons sampled in the soil group.

Initial SOC content to the 30-cm depth for each SLC polygon was taken from the Soil Carbon Layer Database (Tarnocai, 1994), which is the most comprehensive database on SOC for all of Canada.

Simulations

The effect of tillage practices on SOC was simulated using the Century model for the Prairie provinces. The dynamics of SOC under conventional tillage practices were simulated for all polygons, whereas simulations of no-tillage practices were carried out only for polygons in which the no-tillage accounted for at least 5% of the total agricultural area. For all polygons, Century runs were carried out from 1910 to 1996. In order to better represent changing tillage and cropping practices, the runs were broken into four or five time blocks. Reductions in summer-fallow were reflected in the Century analysis by exchanging some of the fallow rotations with more intensive rotations in latter blocks.

The change in soil carbon stocks was compared with the control run 10 years after the introduction of the management changes. The carbon coefficients, averaged over the 10-year period, were determined by weighting the fraction of crop rotation, soil texture, and soil group:

Equation A3-21:

$$C = \Sigma_g F_g (\Sigma_t F_t (\Sigma_r F_r R_r))$$

where:

C = carbon coefficient
g = number of soil groups
F_g = proportion of area covered by soil group
t = number of soil textures
F_t = proportion of area covered by soil texture
r = number of crop rotations
F_r = proportion of area covered by crop rotation
R_r = carbon coefficient for a crop within a soil texture and soil group

The land management activities for which the Century-derived CO_2 coefficients were negative indicated a sink of CO_2, while a positive coefficient indicated a source of CO_2.

Results

From the Century simulations, it was estimated that the overall rate of SOC loss from agricultural soils in Canada for 1990 was 39.1 kg/ha per year (Smith et al., 1997). This implies that 1.93 Mt of SOC (7.05 Mt of CO_2) were lost from agricultural soils in Canada. In 1990, at the provincial level, Alberta had the highest rate of SOC loss, at 74.5 kg/ha per year, followed by Manitoba, with 66.1 kg/ha per year. In Ontario, Quebec, and the Atlantic provinces, the average provincial rate of SOC loss was less than 35 kg/ha per year. Higher SOC loss rates were typically found in soils with coarser texture and greater native SOC content.

Uncertainties

Uncertainty in the model estimates is attributed to model error and variance in input parameters. Given that the model has been calibrated to estimate reasonable average output, most of the estimate uncertainty is attributed to the variance in input parameters. Sensitivity analysis (±20%) of six input variables was carried out for three major soil groups in Canada. The results showed that the level and ranking of sensitivity of each input variable were different within each soil group. On average, in descending order, net CO_2 emission estimates were most sensitive to air temperature, yield, fertilizer application rate, precipitation, bulk density, and clay content.

Given the high degree of spatial variability and poor knowledge on cropping history, there is a high degree of uncertainty associated with the CO_2 estimates provided by the Century model. Comparisons of Century outputs with field measurements suggest that further refinements are required to improve the reliability of the model in predicting soil carbon change in response to no-till practices (McConkey, 1998). The Century model has tended to underestimate the rate of carbon gain from carbon-conserving practices on the prairies, but overestimate the rate of gain in eastern Canada (Smith et al., 1997).

A3.2.2.2 Lime Application

Limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) is often used to neutralize acidic soils, increase the availability of soil nutrients, in particular phosphorus, reduce the toxicity of heavy metals, such as Al^{3+}, and improve the crop growth environment. During this neutralization process, CO_2 is released in the following bicarbonate equilibrium reactions that take place in the soil:

$CaCO_3 + 2H^+ = CO_2 + Ca^{2+} + H_2O$

$CaMg(CO_3)_2 + 4H^+ = 2CO_2 + Ca^{2+} + Mg^{2+} + 2H_2O$

The rate of release will vary with soil conditions and the types of compounds applied. In most cases where lime is applied, applications are repeated every few years. Thus, for the purposes of the inventory, it is assumed that the addition rate of lime is in near equilibrium with the consumption of lime applied in previous years. Emissions associated with the use of lime can be calculated from the amount and composition of the lime applied annually.

Data Sources

There is no single source of data for lime application on agricultural soils. The quantity of lime used for agricultural purposes is not collected by Statistics Canada or by the Canadian Fertilizer Association. Lime usage data were retrieved directly from the Western Canada, Atlantic, Ontario, and Quebec fertilizer associations for the years 1990–1996 and updated in 2003 for the years 1997–2003.

Methodology

Emissions of CO_2 are calculated from the respective stoichiometric relationships that describe the breakdown of limestone and dolomite into CO_2 and other minerals. The calculation of the amount of CO_2 released as a result of limestone application is as follows:

Equation A3-22:

$$CO_2 = X * 44/100$$

where:

X = annual limestone consumption (t/year)

44/100 = the ratio of the molecular weight of CO_2 to the molecular weight of limestone

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Similarly, the calculation for the amount of CO_2 released as a result of dolomite application is shown in Equation A3-23:

Equation A3-23:

$$CO_2 = 2 * X * 44/184.3$$

where:

X = annual consumption of dolomitic lime (t/year)

44/184.3 = the ratio of the molecular weight of CO_2 to the molecular weight of dolomite

---

If the type of lime was not known, the lime was assumed to be composed of 50% calcitic lime and 50% dolomitic lime.

Uncertainties

The uncertainty associated with emissions from this source is due to the uncertainty associated with annual lime consumption activity data. The uncertainty associated with lime consumption is expected to be low to moderate. Thus, the overall uncertainty associated with this source of emission estimates is expected to be low to moderate.

A3.2.2.3 Cultivation of Organic Soils

Data Sources

Areas of cultivated histosols at a provincial level are not covered in the Census of Agriculture. In the absence of these data, consultations with numerous soil and crop specialists across Canada have been undertaken (G. Padbury and G. Patterson, personal communication). Based on these consultations, the total area of cultivated organic soils in Canada is 15 654 ha.

Methodology

The IPCC default methodology used to estimate emissions is based on the rate of CO_2 released per unit land area. The emissions are calculated by multiplying the total area of cultivated histosols by an emission factor.

Equation A3-24:

$$CO_2 = A_{OS} * EF$$

where:

A_{OS} = area of organic soils that is cultivated for annual crop production

EF = emission factor (tonnes of CO_2 loss per hectare per year)

An emission factor of 10 t CO_2/ha per year is adopted (Glenn et al., 1993).

Uncertainties

The uncertainty associated with emissions from this source is due to the uncertainties associated with the area estimates for the cultivated histosols and the emission factor. The uncertainty associated with the area estimate is expected to be low to moderate. The uncertainty associated with the emission factor is assumed to be moderate. Thus, the overall uncertainty associated with this source of emission estimates is expected to be moderate.

A3.2.3 LAND CONVERSION

The current approach to estimating the extent of land-use changes in the Canadian landscape is based on the Census of Agriculture. Prior to the 2004 submission, the base data consisted of the net change in farmland area published by Statistics Canada for each Canadian province. Yet it was recognized that net changes could mask very different combinations of local and regional gains and losses of farmland in the vast Canadian agricultural ecumene. Because of the differing rates of carbon emissions or removals, the GHG fluxes associated with a net change within a given jurisdiction will almost certainly differ from the sum of emissions resulting from land conversion and removals by regrowing vegetation. The coarseness of the spatial scale over which net land-use changes were assessed was a major source of uncertainty.

To alleviate this problem, a time-series analysis of the 1991 and 2001 Census data was conducted at a spatially refined scale, using Census Consolidated Subdivisions (CCSs) as the base geography. With some exceptions, the CCS base represents the finest geographical scale at which agricultural data are made publicly available by Statistics Canada. Data at finer scales exist (Enumeration Areas), but their use would introduce additional uncertainty because of a greater spatial disconnect between land holdings and their owners or operators.

The first step consisted of reconciling CCS boundaries in 1991 and 2001, so that the agricultural land uses could be compared for identical areas. A detailed protocol was established for checking the Census geography and aggregating neighbouring CCS areas affected by changes between 1991 and 2001 using GIS (Figure A3-4). This process left 1639 analysis units, compared with the 10 analysis units when net land-use change was estimated at the provincial level.

FIGURE A3-4: **CCS Areas Affected by Changes between 1991 and 2001**

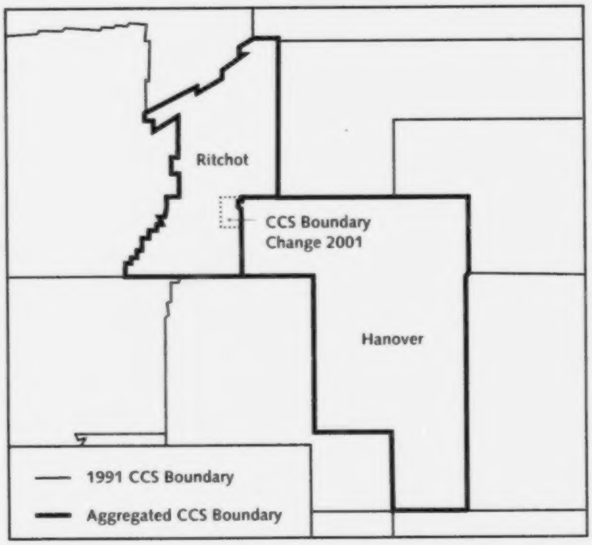

Table A3-22 outlines the three land-use variables compiled from the 1991 and 2001 Censuses of Agriculture for time-series analysis. Of the three, cropland and pasture areas are the most directly related to the land-use classes associated with GHG reporting. In comparison, changes in total farm area reflect more general trends in land use within the agricultural

TABLE A3-22: Census Variables Used for the Determination of Changes in Cropland and Pasture Areas Over the 1991–2001 Decade

Composite Variable	Census of Agriculture Variable	Census Definition	Available for Census Year 1991	Available for Census Year 2001
Cropland	Total land in crops	Includes all areas reported for field crops, fruits, vegetables, nursery products, and sod	Yes	Yes
	Summer-fallow land	Includes areas of idle land that have not been worked	Yes	Yes
Pasture	Tame or seeded pasture	Land that has been cultivated and seeded or drained, irrigated, fertilized, or controlled for brush or weeds; does not include areas to be harvested for hay, silage, or seed	No	Yes
	Natural lands for pasture and grazing	Refers to native pasture, native hay, rangeland, grazeable bush, etc.	No	Yes
	Improved lands for pasture, grazing, or hay	Improved by seeding, draining, irrigating, fertilizing, brush or weed control	Yes	No
	Unimproved land for pasture, grazing, or hay	Includes native pasture, native hay, rangeland, grazeable bush, etc.	Yes	No
Total Farm Area	Total area of farms	Sum of all crops, pasture, summer-fallow, and other land. Note: "Other land" includes farm buildings, barnyards, lanes, greenhouses, and other non-agriculture producing land areas such as marshes and woodlots.	Yes	Yes

ecumene. Summer-fallow land was added to the total land in crops to create the variable cropland. The land-use variable pasture represented a summation of improved land for pasture and unimproved land for pasture in 1991 and tame or seeded pasture and natural lands for pasture in 2001; this variable was taken as the best estimate of "managed grasslands."

Gains and losses in cropland, pasture, and total farm area were calculated separately for each of the 1639 spatial units from the gross change in land area (ha) of these variables between the 1991 and 2001 Censuses. Gross gains were represented by a positive change in land area and gross losses by a negative change in land area. A GIS overlay procedure was used to allocate these gross land-use changes to each of the 15 Canadian ecozones (Marshall et al., 1999). If a CCS straddled two ecozones, the gains and losses were disaggregated at the ecozone level using an area-weighted approach in the GIS.

For lack of better information, in each ecozone, fixed parameters were used to assign the source of new cropland and pastures (forests or pastures, see Table A3-23) and the end uses of lost cropland and pastures (to forest, pastures, or croplands, see Table A3-24).

TABLE A3-23: Origins of New Cropland and Pastures, 1991–2001

	Proportions of New Cropland and Pasture Area Derived from Forest and Pastures (%)		
Final Land Use	Cropland		Pasture
Initial Land Use	Forest	Pasture	Forest
Boreal Zone	0.4	0.4	0.5
Temperate Zone — Prairies	0.2	0.5	0.3
Temperate Zone — Other	0.1	0.6	0.3

TABLE A3-24: Proportion of Lost Cropland and Pastures Reverting to Forests or Pastures, 1991–2001

Ecological Zones			End Uses of Lost Cropland and Pasture (%)			
		Initial Land Use:	**Cropland**		**Pasture**	
		Final Land Use:	**Forest**	**Pasture**	**Forest**	**Cropland**
Boreal	Boreal Cordillera and Taiga Plains		0.1	0.6	0.2	0.6
	Boreal Shield		0.2	0.4	0.2	0.4
	Boreal Plains		<0.1	0.6	0.15	0.6
Temperate	Atlantic Maritime		0.15	0.4	0.2	0.5
	Mixedwood Plains		<0.1	0.3	<0.1	0.5
	Prairies		0.05	0.5	0.15	0.5

In terms of the area affected, urban expansion represents a relatively minor, yet significant, land-use change. Based on the most recent data on urbanization (Statistics Canada, 2005), approximately 45 kha of lands are converted annually to urban areas. It is estimated that 25% of urban expansion is at the expense of forestlands, and 65% was cropland, grassland, or abandoned agricultural land.

Equation A3-25 illustrates the generic approach for estimating carbon losses from the biomass pool upon land-use change. The average annual rate of land conversion, developed for the 1991–2001 decade, was assumed to have remained constant over the past two decades. The total area of land converted in any one year is therefore estimated as 20 times the average annual conversion rate. There is no information on biomass burning practices used for land conversion or on the proportion of biomass left to decay after the removal of the vegetation cover. It was assumed that 90% of all the potential changes in carbon density occur as CO_2 emissions during the inventory year, where potential changes were estimated as the difference between pre- and post-conversion equilibrium biomass. Aboveground forest biomass before conversion was obtained from the Canadian Forest Service (Table 6 in Penner et al., 1997), while IPCC default data were used for pre- and post-conversion biomass on pastures (Table 3.4.9 in IPCC, 2003). Biomass on cropland was assumed to equal zero.

Equation A3-25:

$$\textbf{C emissions} = A * (AGB_{post} - AGB_{pre}) * F\_oxidized_{on\text{-}site} * C_{fraction}$$

where:

C emissions = carbon stock changes in the aboveground biomass pool upon land conversion (t C/year)

A = area of land subject to conversion in inventory year (ha)

AGB_{post} = average equilibrium aboveground biomass post-conversion (t dry mass/ha)

AGB_{pre} = average equilibrium aboveground biomass prior to conversions (t dry mass/ha)

$F\_oxidized_{on\text{-}site}$ = fraction of potential biomass losses emitted on site (0.90)

$C_{fraction}$ = carbon fraction of biomass (0.5)

The conversion of forest or agricultural land generally results in the emission to the atmosphere of soil carbon. As shown in Equation A3-26, converted areas are multiplied by the estimated carbon content of the soil prior to conversion to obtain the total annual potential carbon losses. In the case of land conversion to cropland, 22% of this amount is expected to be emitted over a 25-year period (from data in Dumanski et al., 1998). Equilibrium carbon contents were derived for pre-conversion temperate and boreal forest soils (ESSA Technologies Ltd., 1996). They include both roots and mineral soils and for this reason may overestimate the initial soil carbon contents. Pre-conversion carbon contents in grassland soils were taken from Tarnocai (1996).

Equation A3-26:

$$C\ emissions_{25\ yr} = A * SOC_{pre} * F\_oxidized_{25\ yr}$$

where:

$C\ emissions_{25\ yr}$ = carbon stock changes in the soil organic carbon pool over the 25-year period post-conversion (t C)

A = area of land subject to conversion (ha)

SOC_{pre} = average equilibrium soil organic carbon prior to conversion (t C/ha)

$F\_oxidized_{25\ yr}$ = fraction of soil organic carbon oxidized over the 25-year period post-conversion

The current land conversion time series being limited to an annual average derived over the 1991–2001 decade, the assumption is made that the rate of land conversion has remained constant over the past two and a half decades. Emissions are simply estimated by multiplying $C\ emissions_{25\ yr}$ by the annual average area of forest land or agricultural land converted. Improved time series of land conversion are under development.

Abandoned land that is reverting to forest slowly accumulates carbon in both the biomass and soil carbon pools. The annual carbon accumulation is estimated as illustrated in Equations A3-27 and A3-28.

Equation A3-27:

$$C\ acc_{AGB} = A * R_{AGB} * C_{fraction}$$

where:

$C\ acc_{AGB}$ = annual rate of carbon stock changes in the aboveground biomass pool on land reverting to forest (t C/year)

A = total area of land reverting to forest (ha)

R_{AGB} = annual rate of aboveground biomass accumulation (t dry mass/ha per year)

$C_{fraction}$ = carbon fraction of biomass (0.5)

The total area of land reverting to forest in any one inventory year is equal to 20 times the average annual rate in the 1991–2001 period. The annual rates of aboveground biomass accumulation on lands converted or reverting to forests were taken from work done for the Canadian Forest Service (ESSA Technologies Ltd., 1996); they are considerably lower than the IPCC default values (0.21 versus 0.4–1.5 t dry mass/ha for boreal forest; 0.95 vs. 3.0–4.0 t dry mass/ha for deciduous temperate forests; IPCC, 2003, Table 3.A.1.5), but are deemed more representative of Canadian conditions. These growth rates are approximations only, since in reality they vary with previous land uses, location, site conditions, and the time elapsed since land management activities were discontinued.

Equation A3-28:

$$C\ acc_{soil} = A * R_{soilC}$$

where:

$C\ acc_{soil}$ = annual rate of organic carbon changes in the soil pool on land reverting to forest (t C/year)

A = total area of land reverting to forest (ha)

R_{soilC} = rate of organic carbon accumulation in the soil pool (t C/ha)

Due to the lack of better information, upon land conversion to forest, soil carbon is assumed to accumulate linearly over a 100-year time horizon. The annual rates of soil carbon sequestration were obtained by dividing by 100 the difference in equilibrium soil carbon densities between the expected equilibrium endpoint and the pre-abandonment land use. Rates of soil carbon sequestration upon vegetation regrowth are 0.33 t C/ha per year (boreal forests), 0.40 t C/ha per year (temperate forests), and 0.27 t C/ha per year (grasslands) (ESSA Technologies Ltd., 1996). The total land area reverting to forest is the same as in Equation A3-27.

Uncertainties

As in forest management, uncertainties in the land-use change sector pertain to both methodology and data. The greatest source of uncertainty stems from the lack of harmonization between information sources: the Census of Agriculture, the provincial forest inventories, and other land-use information systems do not use the same base geography. Even with spatially referenced data,[46] inconsistent spatial frameworks do not allow the direct tracking of land transfers between land-use classes across land-use information systems. Thus, it is impossible at this point to accurately track land transfers between main land uses and determine, for example, the extent to which managed forests are encroached upon by agricultural expansion.

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[46] Spatially explicit or georeferenced information refers to the exact location, while spatially referenced information points to an area with which an event is associated.

The application of a few pre- or post-conversion carbon densities certainly generates inaccuracies in the estimated emissions and removals. Moreover, different practices in the removal of vegetation cover and topsoil, as well as mitigation and remediation activities, have a significant influence on the impact of land-use changes. At the present time, these are poorly documented, if at all, and constrain the development of more accurate estimates of GHG fluxes.

The linear interpolation for in-between Census years and the application of an annual average to the entire 1990–2003 period may mask important spatial and temporal trends. Finally, while the time-series analysis of Census data represents a significant improvement in the assessment of land-use changes, the nature of Census geography and variable data, the dissemination policy, and the methods used to attribute the observed changes to the source and end land uses all generate uncertainties. Work is under way to reduce these as much as possible.

Some important land conversion activities are still omitted — notably, the conversion of forest land to non-urban roads, mines, hydroelectric reservoirs, and oil and gas infrastructure.

A3.2.4 ESTIMATION OF DELAYED CO_2 EMISSIONS FROM HARVESTED WOOD PRODUCTS (HWPs)

In addition to the default method, four alternative approaches for carbon accounting in HWPs have been proposed: stock change, production, atmospheric flow, and simple decay. The box on the next page provides a brief description of each approach. Although these approaches yield the same net carbon exchange to the atmosphere on a global level, they differ on a national level in the way in which they account for the time and place of emissions.

As a basis for comparison, emissions associated with harvested material are estimated for all approaches. These harvested emissions are calculated as follows:

IPCC Default:

HE = IRW + Fuelwood + Firewood

Stock Change:

HE = IRW + Fuelwood + Firewood - Carbon in Domestic Long-lived Commodity + Inherited Emissions from Domestic Long-lived Commodity

Production:

HE = IRW + Fuelwood + Firewood - Total Commodity Production + Inherited Emissions from Commodity Produced in Previous Years

Atmospheric Flow:

HE = Fuelwood + Firewood + Roundwood Processing Wastes + Inherited Emissions from Long-lived Commodity Consumed in Previous Years

and

Roundwood Processing Wastes = Total Roundwood Consumption - Commodity Production

where:

HE = carbon emitted during the inventory year from material harvested in previous and current years

IRW = carbon in industrial roundwood harvested in the current inventory year

Fuelwood = carbon in fuelwood harvested in the current inventory year

Firewood = carbon in the firewood consumed in the current inventory year

Consumption = production + imports - exports

For Canada, harvest emissions in 2003 vary from 225 Mt (IPCC default) to 140 (atmospheric flow), 183 (production), or 208 Mt (stock change), depending on the approach selected.

Note that delay in carbon emissions due to storage in HWPs is taken into acccount only for long-lived (>5 years) commodities. The carbon stored in short-lived commodities, including fuelwood and firewood, is assumed to be emitted upon harvest. To date, the calculations have included only semi-processed commodities (e.g., sawnwood, pulpwood, wood-based panels, paper and paperboard, and other industrial roundwood). It is not feasible at present to develop a system that would monitor the paths of carbon stored in HWPs (HWP-C) from harvest to consumer products.

Further elaboration of these approaches is planned, based on the IPCC report on Good Practice Guidance for the LULUCF Sector (IPCC, 2003).

Overview of Approaches to Account for Carbon Storage in Harvested Wood Products

In the **IPCC default approach**, only the net change in forest carbon stocks is accounted for. Emissions from harvests are treated as though they are 100% released as CO_2 to the atmosphere in the year and country of harvest. Carbon storage in wood products is not considered.

The **atmospheric flow** approach tracks carbon emissions and removals associated with the harvest, manufacturing, and consumption of wood products within national boundaries. Its intent is similar to the general methodology for estimating fossil fuel emissions and provides a more accurate reflection of when and where harvest emissions actually occur.

The **stock change** approach accounts only for the net carbon stock change in the domestic wood product reservoir, e.g., HWP-C in all long-lived commodities within the national territory, after imports and exports. The difference between the stock change and atmospheric flow accounting lies in the treatment of exported products (which are significant in Canada). In the stock change approach, carbon in all exported wood products and commodities exits the domestic stock and hence is considered an emission to the atmosphere.

The **production** approach accounts for the changes in carbon stocks of domestically harvested wood and commodities derived from this domestic wood, regardless of their actual location. The accounting boundaries hence encompass the entire export market.

The **simple decay** approach also accounts for the delayed emissions from all HWP-C from domestically harvested wood, but in a simplified way, by applying decay curves standardized by product categories.

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ANNEX 4: COMPARISON OF SECTORAL AND REFERENCE APPROACHES

This annex provides a description of the relevant information on the national energy balance for the comparison between Canada's sectoral approach and reference approach.

A4.1 REFERENCE APPROACH METHODOLOGY

A4.1.1 GENERAL

As requested by the UNFCCC and to ease the comparison between the reference and the sectoral approaches, the reference approach this year is based on GHV of fuels, which is the standard in Canada. For the most part, the IPCC-designated methods are followed for this evaluation. Fuel quantities are recorded from the RESD (Statistics Canada, #57-003) and entered in their natural units (typically megalitres, thousands of cubic metres, kilotonnes, and gigalitres). Apparent consumption is determined, and country-specific energy conversion factors and carbon emission factors are used to calculate the carbon content and emissions. When necessary, the carbon emission factors (t C/TJ) are derived using the IPCC default (IPCC/OECD/IEA, 1997) and NHV and converted to GHV using the OECD conversion factor of 95% for solid and liquid fuels.

A4.1.2 CRUDE OIL

The value listed as "crude oil production" has been adjusted to include the inter-product transfer that would account for crude oil consumed to supply still gas in the oil sand and bitumen upgraders. Producer-consumed upgrader petroleum is not accounted for in marketable production statistics because synthetic crude oil production statistics are based on marketable volumes of crude produced, not on volumes of bitumen extracted. All calculations are made using default IPCC values for the carbon emission factors.

A4.1.3 NATURAL GAS LIQUIDS (NGLs)

NGLs are accommodated by representing them as a virtual composite mixture of ethane, propane, and butane. Dependent upon the annual proportions, an energy conversion factor (TJ/unit) and carbon emission factor (t C/TJ) for that year are generated.

A4.1.4 GASOLINE

This category is a combination of *motor gasoline* and *aviation gasoline*, with the former dominating the total.

A4.1.5 LIQUEFIED PETROLEUM GAS (LPG)

LPGs are accommodated by representing them as a virtual composite mixture of propane and butane produced by the refineries. Dependent upon the annual proportions, an energy conversion factor (TJ/unit) and carbon emission factor (t C/TJ) for that year are generated.

A4.1.6 BITUMEN

All calculations are made using default IPCC values for the carbon emission factors.

A4.1.7 OTHER OILS

This category includes stored carbon due to other products from Table 1-A(d) of the CRF.

A4.1.8 OTHER AND SUB-BITUMINOUS

Other bituminous and sub-bituminous carbon emission factors were based on a mixture of what was imported and exported annually.

A4.1.9 NATURAL GAS

The value listed as "natural gas production" in the RESD has been reduced to compensate for the inter-product transfer (which accounts for the natural gas being used as a source of hydrogen in oil sand upgrading).

A4.1.10 BIOMASS

Solid biomass includes Canadian industrial and residential sources, whereas liquid biomass addresses spent pulping liquor. All calculations are made using default IPCC values for the carbon emission factors.

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ANNEX 5: ASSESSMENT OF COMPLETENESS

Although this inventory report serves as a comprehensive assessment of anthropogenic GHG emissions and removals in Canada, some categories have not been included.

A5.1 ENERGY

Overall, the Energy Sector of the national inventory provides a full estimate of all significant sources. The following subsections list categories that are not currently estimated and that may represent a source in their particular subsector, but which do not affect the overall completeness of the inventory due to their relatively small contributions.

A5.1.1 FUEL COMBUSTION

Emissions from the combustion of waste fuels (e.g., tires, solvents, etc.) for the production of energy at industrial facilities (e.g., cement kilns) are not included. An appropriate data collection mechanism has not yet been identified for this emission source. Further emission factor research is needed to ensure that there is no double-counting of GHG emissions from the non-energy use of fossil fuels (reported under the Industrial Processes Sector). Where IPCC default factors are currently applied, it is assumed that these account for GHG emissions from the non-energy use of fossil fuels and disposal of its products (e.g., tires used as waste fuels by the cement production industry).

A5.1.2 EMISSIONS FROM COMBUSTION OF LANDFILL GAS

Emissions from the combustion of captured landfill gas used as a fuel source to generate heat or power are currently addressed in the Solid Waste Disposal on Land subsector (Chapter 8). In future, emissions from the use of landfill gas as a fuel source will be allocated to the Energy Sector, as suggested by the IPCC methodological guidelines.

A5.1.3 FUGITIVE EMISSIONS

Flaring and fugitive emissions from industrial facilities such as petroleum refineries, chemical plants, and metallurgical coke production are not accounted for (fugitive emissions from oil and gas production facilities are inventoried) in the current GHG inventory. Appropriate data collection mechanisms and emission estimation methodologies have not yet been identified for chemical plants and metallurgical coke production. A study was conducted in 2004 to assess emissions from the petroleum refinery industry. Results from the study will be reviewed and may be used to develop a methodology to estimate flaring and fugitive emissions from petroleum refineries.

A5.2 INDUSTRIAL PROCESSES

Overall, the Industrial Processes Sector of the national inventory provides a comprehensive estimate of all significant sources. The following subsections list sources that are not currently estimated and that may represent a source in their particular subsector, but their magnitudes are assumed to be small and not affecting the overall completeness of the GHG inventory in a major way.

A5.2.1 MINERAL PRODUCTS

CO_2 emissions attributed to limestone use in the pulp and paper industry are not currently inventoried. New data sources are being evaluated for this emission source. Furthermore, emissions from asphalt roofing, road paving with asphalt, and glass production (other than those related to the use of limestone and soda ash in the process) are not estimated and are thought to be negligible. CO_2 emissions from magnesite (carbonate)-based production of magnesium are not estimated. Activity data pertaining to this type of production of magnesium in Canada are not currently available.

A5.2.2 CHEMICAL PRODUCTION

N_2O emissions associated with the production of chemicals other than nitric and adipic acids are not estimated. Production of chemicals other than nitric acid and adipic acid may be a source of N_2O; however, more research is required to determine its significance.

Similarly, there are insufficient data available to estimate CH_4 emissions from chemical manufacturing processes in Canada, although they are thought to be insignificant.

Process-related CO_2 emissions from adipic acid production are not inventoried and are considered negligible.

Recovered CO_2 from ammonia manufacturing is used in the production of fertilizer destined for export markets outside Canada. This is a sink category that is not included in the inventory. Efforts will be made to acquire data and develop a methodology, such that CO_2 trapped in exported products (e.g., urea) can be estimated and subtracted from CO_2 emissions from ammonia production.

A5.2.3 METAL PRODUCTION

Emissions of SF_6 attributed to its use as a cover gas in magnesium casting operations are now inventoried within this NIR.

CH_4 emissions associated with the production of metals are not estimated and are thought to be insignificant.

A5.2.4 PRODUCTION AND CONSUMPTION OF SF_6

Emissions of SF_6 attributed to its use as an insulating gas in electrical equipment are now inventoried. There seems to be a minor use of SF_6 in the aluminium production industry, but SF_6 emissions from this source are currently not included in the inventory. The possibility of obtaining SF_6 emission data from the AAC will be investigated.

Data on PFCs used in fire extinguishers, aerosols, and electrical equipment, HFCs used in electrical equipment, and SF_6 used in semiconductors are currently unavailable. As a result, emissions arising from these sources are not inventoried. Also, there is currently no information on the import, export, or destruction of SF_6.

A5.3 SOLVENT AND OTHER PRODUCT USE

In this sector, only N_2O emissions associated with the use of anaesthetics and propellants are estimated. Emissions for other sources, such as paint application, degreasing, and dry cleaning, are not estimated, since their corresponding activity data are currently not available.

A5.4 AGRICULTURE

Overall, the Agriculture Sector of the national inventory provides a complete estimate of the significant sources. The following list includes sources that are not currently estimated. Most of these are considered to be minor sources.

A5.4.1 ENTERIC FERMENTATION AND MANURE MANAGEMENT

Some smaller animal categories, such as domestic deer, elk, and llamas, have not yet been included. Due to their relatively low populations, these are considered to be minor sources.

A5.4.2 RESIDUE BURNING

Residue burning is practised to a small extent in Canada. Flax residue, for example, is generally burned. This is considered to be a minor source of emissions. An appropriate data collection method for this source has not been established.

A5.4.3 RICE PRODUCTION

CH_4 emissions from rice production are not currently inventoried, as rice production is quite limited in Canada. An appropriate data collection method for this source has not been established.

A5.5 LAND USE, LAND-USE CHANGE AND FORESTRY

As mentioned at the beginning of Chapter 7, the new LULUCF reporting format represents more than a restructuring of the information; it calls for the development of several new estimates, in addition to significant enhancements in estimate development procedures, in conformity with the good practices provided in IPCC (2003). The ongoing development of Canada's LULUCF inventory system, briefly outlined in the Overview section of Chapter 7, aims to address these new requirements. In light of the complexity of these tasks, the full implementation of the IPCC report will span several years, with the highest priorities given to categories that are believed to have the greatest contribution to the sector. This section briefly outlines the known gaps in the current submission.

A5.5.1 FOREST LAND

Currently, only CO_2 removals associated with aboveground biomass of managed forests are included in the inventory; all carbon transferred from biomass to other pools is assumed to be emitted to the atmosphere. To include other forest ecosystem carbon pools (belowground biomass, litter, coarse debris, and soils) without introducing bias, all the carbon exchanges among these pools, and between each one and the atmosphere, should be estimated. For example, using default root:shoot ratios (IPCC, 2003: Table 3A1.8 and Equation 3.2.5) without supplementary data on belowground carbon turnover and decay would result in a gross overestimate of net carbon sequestration in forests. Ongoing work will address these gaps in the shortest possible time frame.

The current estimate of emissions from land converted to forest land includes only cropland and grassland conversion to forest land. Emissions and removals from the conversion of wetlands, settlements, and other land to forest have not been estimated; their contribution to the sector is deemed minor.

A5.5.2 CROPLAND

The current estimate in the Land Converted to Cropland category includes only CO_2 emissions due to forest and grassland conversion to cropland. Non-CO_2 emissions from biomass burning, as well as GHG emissions and removals from the conversion of wetlands, settlements, and other land to cropland, have not been estimated.

A5.5.3 GRASSLAND

Estimation of GHG emissions and removals associated with Grassland Remaining Grassland is a new LULUCF reporting requirement (IPCC, 2003); estimates are under preparation. The current estimate in the Land Converted to Grassland category includes only forest conversion to grassland. Emissions and removals from the conversion of cropland, wetlands, settlements, and other land to grassland have not yet been estimated.

A5.5.4 WETLANDS

Estimation of GHG emissions and removals in the wetlands category is a new reporting requirement (IPCC, 2003); estimates are under preparation.

A5.5.5 SETTLEMENTS

The current estimate in the Land Converted to Settlements category includes only forest and cropland loss to urbanization. Emissions and removals from the conversion of grassland, wetlands, and other land to settlements have not been estimated, nor have forest conversion to settlement subcategories, such as infrastructure development or industrial resource extraction. More complete estimates are under preparation.

A5.6 WASTE

This category is for the most part complete, with the exception of the following.

A5.6.1 INDUSTRIAL WASTEWATER TREATMENT SYSTEMS

An appropriate data collection mechanism has not been identified for this source of emissions. A study planned for 2005 will provide for the activity data and methodology to estimate emissions from this subsector and their inclusion in the inventory. Another study will look into the anaerobic CH_4 emissions from tailings ponds in the oil sands operations in Canada.

A5.6.2 WASTE INCINERATION

Emissions of CH_4 from MSW incineration and emissions of N_2O from sewage sludge are not estimated due to lack of underlying emission research. A study on incineration-related GHG sources in 2005 will provide emission factors and activity data for these source categories for their inclusion in the inventory.

REFERENCES

IPCC (2003), *Good Practice Guidance for Land Use, Land-Use Change and Forestry*, Intergovernmental Panel on Climate Change National Greenhouse Gas Inventories Programme. Available online at: www.ipcc-nggip.iges.or.jp/lulucf/gpglulucf_unedit.html.

ANNEX 6: QUALITY ASSURANCE AND QUALITY CONTROL

The application of QA/QC procedures is an essential requirement in the GHG inventory development and submission processes in order to ensure and improve transparency, consistency, comparability, completeness, and confidence in the national emission and removal estimates for the purposes of meeting Canada's reporting commitments under the UNFCCC. Two basic conditions have to be met so that control procedures qualify as QA/QC: firstly, checks and reviews have to be performed by staff not involved in the preparation of the inventory estimates; and secondly, their nature, outcome, and the appropriate corrective actions have to be documented.

The following sections describe the overall framework for the QA/QC plan that the GHG Division is currently developing and implementing. A description is also provided of the various formal procedures already implemented in the development of the 1990–2003 GHG inventory submitted in April 2005 and of the planned improvements. Any category-specific QA/QC activities are described, where applicable, in Chapters 3–8 in the QA/QC subsection attached to each category.

A6.1 FRAMEWORK OF A QA/QC PLAN FOR THE NATIONAL INVENTORY

Informal QC has been performed regularly over the inventory, and a formal external review process has been in place for many years, as described in previous national inventory reports. The design of a formal QA/QC plan meeting the UNFCCC and IPCC Good Practice Guidance requirements was initiated with the development of a QA/QC framework (SNC Lavallin, 2004). This framework provides the basis for the QA/QC program, the first step of which is the implementation of Tier 1 QC (see below). The plan, to be further elaborated over the course of 2005–2006, is seen as an integrated approach to managing inventory quality, working towards continuously improved emission and removal estimates. It will encompass a quality management cycle that spans several years, ensuring that the complete inventory will have been subject to the full suite of QA/QC procedures at least once.

Staffing of a QA/QC coordinator position is under way, with overall responsibility for the design and implementation of the full plan, including the processes governing expert reviews, audits, verification, and other reviews as required, as well as upgrading the documentation and archiving system. The plan also includes several standard, numbered forms for the consistent documentation of all QA/QC activities conducted in the annual inventory preparation and submission. Forms completed during each annual inventory preparation will be stored in "Activity Books" and archived along with other procedural and methodological documentation.

QA/QC work is moreover coordinated with outside agencies and organizations providing activity data and/or developing actual GHG estimates for Environment Canada (e.g., Statistics Canada, LULUCF partners, industry, etc.) to assess whether the QC and potential QA procedures in their respective data collection systems are in place or are being developed and meet the minimum requirements.

A6.2 QUALITY CONTROL PROCEDURES

QC is designed to provide routine technical checks to measure and control the quality of the inventory, to ensure data consistency, integrity, correctness, and completeness, and to identify and address errors and omissions. Its scope covers a wide range of inventory processes, from data acquisition and handling and application of approved procedures and methods to calculation of estimates and documentation (IPCC, 2000).

For the 2005 inventory submission, 39 inventory categories have been subject to formal Tier 1 QC checks, as described below, in a manner consistent with IPCC Good Practice Guidance. Out of the 39 categories, 32 are key categories identified by both level and/or trend assessments, 2 are key categories identified from the qualitative assessment, and 5 are not key categories. For a number of key categories, the same level of detailed checks was also performed for the subcategories (e.g., agricultural direct and indirect N_2O emissions categories). Due to time and resource constraints, eight key categories did not undergo the formal QC checks: N_2O road transport (level and quality) as well as six other transport sources and one Fugitive source (CH_4 from venting and flaring), which were identified by the qualitative assessment.

Standard Tier 1 QC checks applicable to all categories and listed on Form QP03 (Environment Canada, 2005a) were performed internally by GHG Division staff not directly involved in the development of the GHG estimates for those categories. These formal Tier 1 QC procedures consist of a series of 31 checks being grouped into seven steps integrated at various stages of the inventory preparation process, as follows:

1) raw data collection, acquisition, and handling (e.g., completeness, accuracy of data sources and units, consistency of activity data trend, etc.);
2) data input into model/spreadsheet (e.g., transcription errors, accuracy of units, etc.);
3) GHG emissions and removals estimations (e.g., proper use of units and equations, integrity of files and spreadsheets, sample calculation checks, etc.);
4) treatment of category in sector summary tables and sector trend analysis (e.g., identification of potential trend anomalies, accuracy of aggregation, consistency of estimates, etc.);
5) uncertainty estimates (e.g., completeness, transcription errors, etc.);
6) input of category estimates in the CRF (e.g., consistency and accuracy checks, correct use of notation keys, etc.); and
7) treatment of category in NIR (e.g., consistency between CRF and NIR, accuracy and completeness of references, etc.).

Checks on the documentation and archiving of all the information required to produce the national emissions estimates are in the process of being performed, starting with the key categories. These QC procedures are listed in Form QP10 (Environment Canada, 2005b). In addition, formal cross-cutting QC checks on CRF and NIR assembly and final products were performed prior to final submission and documented in Form QP13 (Environment Canada, 2005c), also archived in the QA/QC Activity Books.

These checks allowed some transcription and calculation errors to be detected and addressed. The QC forms include a record of any corrective action taken and refer to supporting documentation such as phone logs, electronic mail, notes, or additional calculation checks. Both electronic and hard copies of these completed forms and the supporting documentation are archived in the QA/QC Activity Book specific to each inventory category for the 2005 submission. It is anticipated that Tier 1 QC checks for the non-key categories will be performed over the next inventory cycle.

In addition to general Tier 1 QC checks, the QA/QC framework of the national inventory provides for the application of Tier 2 QC checks on a case-by-case basis starting with key categories (for which typically higher tier methodologies are used) and categories where a significant change in method or data has been made. Tier 2 QC procedures are specific to the source or sink category and require a more in-depth technical expertise. For some key categories, Tier 2 QC will be applied in the course of the 2005–2006 inventory cycle. Addressing all of them will constitute a multi-year process.

A6.3 QUALITY ASSURANCE

QA generally consists of independent third-party review activities to ensure that the inventory represents the best possible estimates of emissions and removals and to support the effectiveness of the QC program (IPCC, 2000).

A formal review of the draft GHG estimates takes place over the month of March each year by experts from the EPWG of the National Air Issues Coordinating Committee, a federal-provincial-territorial forum. The draft inventory is also reviewed at the same time by government experts and scientists of Agriculture and

Agri-Food Canada and the Canadian Forest Service of NRCan, among others, under the auspices of the MARS for LULUCF (see also Chapter 7).

In addition, selected underlying data and methods are independently assessed each year by various groups or individual experts in industry, academia, and governments, in particular in the Energy and Industrial Processes sectors (e.g., aluminium, fugitives, etc.). Findings are tracked and documented and feed into the development of improvement work plans.

The Quality Management Cycle will integrate these activities into the QA/QC plan, which will comprise a formal schedule of annual peer reviews, with a focus on category- or sector-specific reviews, as required. It is also planned that an independent audit will be conducted to objectively evaluate how effectively the national system and the general inventory process comply with the minimum QC specifications outlined in the Good Practice Guidance and the QA/QC plan.

REFERENCES

Environment Canada (2005a), *Form No. QP03, Tier 1 QC Procedures, Version 10.0*, February, Gatineau, Quebec, Canada.

Environment Canada (2005b), *Form No. QP10, Documentation and Archiving QC Procedures, Version 2.0*, February, Gatineau, Quebec, Canada.

Environment Canada (2005c), *Form No. QP13, Cross-Cutting Inventory Tier 1 QC Checks, Version 1.0*, February, Gatineau, Quebec, Canada.

IPCC (2000), *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change National Greenhouse Gas Inventories Programme. Available online at: www.ipcc-nggip.iges.or.jp/public/gp/english/.

SNC Lavallin (2004), *Framework for a Quality Assurance and Quality Control Plan*, Prepared for the Greenhouse Gas Division, Environment Canada.

ANNEX 7: UNCERTAINTY

A7.1 INTRODUCTION

Identifying sources of uncertainty in the emission and removal estimates of the GHG inventory and quantifying the magnitudes of the uncertainty are of assistance in defining and prioritizing future improvements to the NIR. Quantitative estimates of the uncertainty can also be used to assess relative importance of the input parameters (e.g., activity data and emission factors) according to their relative contribution to the uncertainty of the respective source category estimates. This information allows prioritized resource allocation to the reduction of uncertainty in inventory estimates.

The UNFCCC Reporting Guidelines on Annual Inventories state that Annex I Parties shall quantitatively estimate the uncertainties in the data used for all source and sink categories using at least the Tier 1 method, as provided in the IPCC Good Practice Guidance. Alternatively, Annex I Parties may use the Tier 2 method in the IPCC Good Practice Guidance to address technical limitations in the Tier 1 method. Uncertainty in the data used for all source and sink categories should also be qualitatively discussed in a transparent manner in the NIR, in particular for those sources that were identified as key sources.

Canada last performed an uncertainty assessment of its 1990 estimates in 1994 (McCann, 1994). In 2003–2004, Canada embarked on a comprehensive study to quantify uncertainty associated with its source categories included in the 2001 GHG inventory (the latest inventory estimates available at the time of study). The study report for this original phase of study was published in September 2004 (ICF, 2004). At the time of the study, the IPCC report on Good Practice Guidance for LULUCF was still under preparation; therefore, the LULUCF Sector was excluded from the assessment.

In early 2005, uncertainty estimates for the oil and gas venting and flaring categories from the first ICF study were revised to take into account newly acquired country-specific uncertainty data (ICF, 2005). The overall trend uncertainty for the 2001 GHG inventory, not previously performed due to the computational limitations, was also estimated but was not reported here, since it has not yet been fully reviewed. All information provided in this annex is drawn from ICF (2004, 2005).

A7.2 SCOPE OF UNCERTAINTY STUDY

The source categories assessed include key categories and various other source categories selected in accordance with an agreed upon uncertainty model. This ensured that the important sources were included while avoiding over-representation of smaller sources with similar activity or emission factor uncertainty data.

A Tier 2 approach was adopted (IPCC, 2000) since a) the inventory estimation methodology is complex and includes several input variables, b) the uncertainty surrounding the input variables is large, c) the variables are correlated between and/or within source categories, and d) the probability distributions underlying the estimates are non-normal. Tier 1 uncertainty analysis was not conducted due to time and resource constraints but will be performed in the future.

Level uncertainty estimates were developed for each inventory source category based on the 2001 estimates (excluding LULUCF) and for the GHG inventory overall. Also developed were trend uncertainty estimates between 1990 and 2001 through Tier 2. The Monte Carlo stochastic simulation technique was used for individual source categories.

The uncertainty ranges were developed for the 2.5th and 97.5th percentiles (95% confidence interval) for source categories. It is assumed that uncertainty ranges for many source categories included in the ICF study can be used for the 2003 GHG inventory estimates, provided that the methods for obtaining activity data and estimates have not changed. For trend uncertainty estimates, the assumption has been that the uncertainty ranges apply to the 2001 inventory estimates only. This is because estimates for the trend uncertainty are more sensitive to the inventory values for base and current years.

A7.3 SUMMARY OF RESULTS

Table A7-1 provides the results of the uncertainty study as they apply to the inventory totals. The overall GHG inventory uncertainty range for Canada's 2001 estimate, as mentioned previously, is assumed to generally apply to the 2003 GHG inventory. Without considering the uncertainty of GWPs, this overall uncertainty is assessed at -3% to +6%; with the effect of GWPs, it is -5% to +10%. This compares with other Annex I Parties' reported uncertainties and reflects the range of uncertainties that such countries would see in their inventories. Further results of the study, on a sector and category basis, are detailed in Tables A7-6 to A7-16 at the end of the annex.

A7.4 APPROACH AND METHODS

A7.4.1 GENERAL CONCEPTS

Emission estimate uncertainty is composed of (i) model uncertainty and (ii) parameter uncertainty. Model uncertainty refers to the uncertainty associated with the estimation methodology (i.e., the mathematical equations or inventory estimation models, such as Emissions = Activity Data × Emission Factor). Model uncertainty results in biased inventory estimates. It can be detected through QA and reduced by developing an appropriate, alternative inventory estimation model.

Parameter uncertainty refers to the uncertainty associated with variables such as Activity Data and Emission Factor and constants used as inputs to the inventory estimation models. Parameter uncertainty can be further divided into (i) random (or statistical) uncertainty and (ii) systematic uncertainty (or bias). While random uncertainty can be estimated statistically, systematic uncertainty can be quantified only through research and analysis. Both random and systematic uncertainty can be quantified through expert elicitation. Although random uncertainty cannot be removed, efforts can be undertaken to minimize it.

Canada's 2001 GHG inventory has been shown to possess all three types of uncertainties mentioned above. While random parameter uncertainty is present in all cases, systematic parameter and model uncertainties have also been found in some categories (e.g., PFCs from aluminium production; see Section A7.5, Analysis of Results).

TABLE A7-1: Quantitative Uncertainty Assessment of Overall National Inventory GHG Emissions for 2001[1]

Emissions by Gas	2003 Inventory Year Estimate kt	Low % relative to inventory estimate[3]	High % relative to inventory estimate[3]	Coefficient of variation %
CO_2	586 066	-4	0	1
CH_4	4 478	-5	35	12
N_2O	162	-8	80	21
HFC (CO_2 eq)	3 090	-22	60	18
PFC (CO_2 eq)[2]	2 760	-70	-60	5
SF_6	4 072	-1	1	0
Total GHG Emissions (CO_2 eq) (without GWP uncertainty)	740 214	-3	6	3
Total GHG Emissions (CO_2 eq) (with GWP uncertainty)	740 214	-5	10	4

Notes:

1 These values were obtained from ICF (2004, 2005) and were associated with 2001 GHG emission estimates. They are assumed to apply generally to the overall 2003 GHG inventory (reported in 2005). At the gas, sector, or category level, this assumption might not hold if data and methodologies have changed significantly (see footnote 2 in particular).

2 The PFC uncertainty estimate relates to the 2001 PFC emission estimate and is not representative of the 2003 emissions. It reflects a method bias that existed in 2001 for PFCs from aluminium smelting that has been corrected through adoption of a Tier 3 emission estimation method.

3 Low and high values indicate the simulated lower- and upperbound emission estimates at a 95% confidence level.

A7.4.2 INPUT DATA FOR THE UNCERTAINTY MODEL

The Monte Carlo method of uncertainty estimation requires specifying the probability distributions underlying every input parameter used in the inventory estimation for each source category. Credibility of the uncertainty estimates developed using the Monte Carlo approach is essentially dependent on the accurate characterization of these probability distribution functions. Because the values of many of the input parameters used for GHG estimation were point estimates, uncertainty ranges associated with the inventory estimates of the input variables were obtained from various best available data sources, consistent with the guidelines provided in the IPCC Good Practice Guidance (IPCC, 2000). The two main sources of uncertainty data were:

1) published references, survey data, sample statistics, and other unpublished reports; and

2) expert elicitations.

The important published references that were used in developing uncertainty for the input variables included McCann (2000), SGA (2000), IPCC Good Practice Guidance (IPCC, 2000), the IPCC Reference Manual (IPCC/OECD/IEA, 1997), and the 2003 NIR (Environment Canada, 2003):

- McCann (2000) developed CO_2 emission factors for fossil fuel combustion, by fossil fuel type, for 1998 and the associated uncertainty ranges for 95% confidence intervals. McCann (2000) recommended CO_2 emission factors for coal (with the exception of anthracite), natural gas, and NGLs. These emission factors were used in the development of the 2001 inventory estimates. Therefore, for purposes of this study, uncertainty estimates developed by McCann (2000) were adopted.
- For marketed refined petroleum products, the CO_2 emission factors used in the 2001 inventory estimation differed from the emission factors reported by McCann (2000). However, based on the recommendation of Dr. John Nyboer of CIEEDAC, the uncertainty associated with the inventory estimates was developed based on the emission factors and the associated uncertainty ranges recommended by McCann (2000).
- SGA (2000) developed the best estimates of CH_4 and N_2O emission factors and uncertainty estimates for fossil fuel combustion. These CH_4 and N_2O emission factor estimates are used in the inventory estimation for stationary and mobile fuel combustion source categories. Consequently, for this uncertainty analysis, the uncertainty ranges developed by SGA (2000) for CH_4 and N_2O were adopted for generating uncertainty estimates for the stationary and mobile fuel combustion source categories.
- In the case of other input variables for which uncertainty data were not available through expert elicitations, uncertainty estimates were developed based on the IPCC-recommended emission factors and/or uncertainty range associated with the emission factors.
- When pertinent uncertainty data were not available from any of these sources, educated estimates of uncertainty in the input variables were developed based on a review of (a) the inventory estimation methodology and the data source used for the 2003 NIR and (b) the recommended estimation methodology and the methodological details provided in the IPCC Reference Manual (IPCC/OECD/IEA, 1997) and the input data selection discussions provided in the IPCC Good Practice Guidance (IPCC, 2000) for that source category, as appropriate.

For many other variables, uncertainty data to characterize the input variables were obtained through expert elicitations. Two sets of expert elicitations were conducted: (i) detailed expert elicitation and (ii) less detailed expert elicitation. Both sets of elicitations were administered using elicitation protocols and differed in terms of the time commitments provided by the experts. The detailed expert elicitation protocol was structured similarly to the well-known Stanford/SRI protocol (Morgan and Henrion, 1990; IPCC, 2000). A pre-elicitation template was used, since it was not possible to obtain significant time commitments from the experts to complete the process.

Table A7-2 provides the list of input parameters for which expert elicitations were sought during this study.

TABLE A7-2: Input Variables Selected for Expert Elicitation — Uncertainty Quantification

Index	Input Variable	Number of Variables	Variable Type	Unit of Measure	Suggested Experts
1	Electricity Generation – Coal Consumption (Canadian Bituminous, Sub-Bituminous, Anthracite, Lignite, and Imported Bituminous) – Provinces of Alberta, Ontario, Saskatchewan, and New Brunswick	5–7	Activity Data and Fuel Consumption	1000 tonnes	Statistics Canada & Canadian Coal Association
1a	Fuel Combustion – Electricity and Heat Generation – Coal Emission Factor – Canadian Bituminous, Sub-Bituminous, Anthracite, Lignite, and Imported Bituminous by Province	5–8	Emission Factors	–	T. McCann
3	Fuel Combustion – Other Sector – Residential CO_2 – Natural Gas and Heavy Fuel Oil, CH_4 and N_2O for Biomass Fuel	5	Activity Data and Fuel Consumption	Cubic metres & kilotonnes	Statistics Canada & Environment Canada (CAC Division)
3a	Fuel Combustion – Other Sector – Residential CH_4 and N_2O for Biomass Emission Factors	2–5	Emission Factors	–	–
4	Fuel Combustion – Manufacturing and Construction – Other Manufacturing – CO_2 – Natural Gas, Heavy Fuel Oil, and Propane	3	Activity Data	Cubic metres	Statistics Canada
5	Fuel Combustion – Manufacturing and Construction – Pulp, Paper and Print – CO_2 Emissions from Natural Gas and Heavy Fuel Oil; CH_4 and N_2O Emissions from Biomass Fuel	5	Activity Data	Cubic metres	Statistics Canada
6	Fuel Combustion – Manufacturing and Construction – Chemical Industries – CO_2 Emissions from Natural Gas and Heavy Fuel Oil	2	Activity Data	Cubic metres	Statistics Canada
7	Fuel Combustion – Manufacturing and Construction – Iron and Steel Industries – CO_2 Emissions from Coke Oven Gas and Natural Gas	2	Activity Data	Cubic metres	Statistics Canada
8	Fuel Combustion – Manufacturing and Construction – Other – Cement, Mining and Construction – CO_2 Emissions from Refined Petroleum Fuel Consumption, Natural Gas, and Bituminous Coal (Canadian Bituminous, Sub-Bituminous, and Import)	5	Activity Data	Cubic metres	Statistics Canada
9	Fugitive Emissions – Oil and Natural Gas – CH_4 Emissions from Conventional Oil Production	1	Activity Data	Cubic metres	Statistics Canada & Clearstone Engineering
10	Fugitive Emissions – Oil and Natural Gas – CO_2 and CH_4 Emissions from Natural Gas Production and Processing, Transmission, and Distribution	5	Activity Data	Cubic metres & kilometres	Statistics Canada & Clearstone Engineering
11	Fugitive Emissions – Oil and Natural Gas – CH_4 Emissions from Flaring	1	Activity Data	Cubic metres	Statistics Canada & Clearstone Engineering
12	Fuel Combustion – Manufacture of Solid Fuels and Other Energy Industries – CO_2 Emissions – Producer Consumed Fuels – Coal and Natural Gas	3	Activity Data	Cubic metres	Statistics Canada
13	Fuel Combustion – Petroleum Refining – CO_2 Emissions from the Consumption of Refined Petroleum Products – Heavy Fuel Oil, Petroleum Coke, and Catalytic Coke	5	Activity Data	Cubic metres	Statistics Canada
13a	Fuel Combustion – Petroleum Refining – CO_2 Emissions from the Consumption of Refined Petroleum Products – Petroleum Coke and Catalytic Coke	2	Emission Factors	–	CIEEDAC – John Nyboer
14	Industrial Processes – CO_2 Emissions from Other and Undifferentiated Production – Non-Energy Fuel Consumption and Feedstock Use	5–8	Activity Data	Cubic metres	Statistics Canada
14a	Industrial Processes – CO_2 Emissions from Other and Undifferentiated Processes – Non-Energy Fuel Consumption and Feedstock Use	5–8	Emission Factors	–	IPCC Guidelines
15	Industrial Processes – N_2O from Adipic Acid Production	1	Emissions	–	DuPont Canada
16	Aluminium Production – CO_2 and PFC Emissions (Plant Production Capacity and Technology)	2–3	Activity Data and Emissions	–	AAC & NRCan
17	Industrial Processes – Ammonia Production	2	Activity Data and Technology Split Factors	–	–
18	Industrial Processes – SF_6 Emissions from Magnesium Production	3	Emissions	–	NPRI and magnesium production industries
19	Industrial Processes – Cement Production	1	Activity Data	–	Minerals Year Book – NRCan
20	Industrial Processes – Iron and Steel Production	1–2	Activity Data	–	Statistics Canada
21	Fugitive Emissions – Coal Mining – Quantity of Surface Coal Mined (Sub-Bituminous, Canadian Bituminous, and Lignite) and Underground Coal Mined by Region	5–8	Activity Data	kt/year	Statistics Canada
22	Fugitive Emissions – Coal Mining – Emission Factor for Coal Mined (Sub-Bituminous, Canadian Bituminous, and Lignite) and Underground Coal Mined by Region	3–5	Emission Factors	kt CH_4/kt coal	Environment Canada reference material

Tables A7-3 and A7-4 show examples of uncertainty assessments obtained through the expert elicitation process and through source document research. Table A7-4 provides more detailed information on the uncertainty, such as the inventory central value, the shape of the probability distribution function, the uncertainty range, and the confidence interval for which the range is quoted.

TABLE A7-3: Sample Input Parameter Uncertainty Estimates Obtained from Expert Elicitation — Activity Data for Quantity of Fuel Consumed (ICF, 2004)

Fuel Consumption Uncertainty Estimates (2001) - in % around the mean value Stationary and Mobile Fuel Combustion		Natural Gas	Still Gas	Motor Gasoline	Kerosene & Stove Oil	Diesel Fuel Oil	Light Fuel Oil	Heavy Fuel Oil	Petroleum Coke	Aviation Gasoline	Aviation Turbo Fuel	NGL - Propane	NGL - Butane	NGL - Ethane	Canadian Bituminous	Sub-Bituminous	Lignite	Anthracite	U.S. (Imported) Bituminous	Coke	Coke Oven Gas
1.A.1	Energy Industries																				
1.A.1.a	Electricity Generation	1	–	–	–	1	1	1	1	–	–	–	–	–	1	1	1	–	1	1	1
1.A.1.b	Petroleum Refining (Upstream & Downstream Oil and Gas Industries)	1	2	–	1	1	1	1	1	–	–	1	1	–	–	–	–	–	–	–	–
1.A.2	Manufacturing Industries and Construction																				
1.A.2.a	Iron and Steel	1	–	–	–	3	–	1	1	–	–	–	–	–	1	–	–	1	–	1	1
1.A.2.b	Non-Ferrous Metals	1	–	–	–	3	–	1	1	–	–	–	–	–	1	–	–	1	–	1	–
1.A.2.c	Chemicals	1	–	–	–	3	2	1	1	–	–	–	–	1	–	–	–	–	–	–	–
1.A.2.d	Pulp, Paper and Print	1	–	–	–	3	2	1	–	–	–	–	–	–	–	–	1	–	1	–	–
1.A.4	Other Sectors																				
1.A.4.a	Commerical/Institutional	3	–	2	1	3	2	2	–	1	1	3	–	–	1	–	–	–	–	–	–
1.A.4.b	Residential	1	–	–	1	–	1	1	–	–	–	1	–	–	1	1	1	–	–	–	–
1.A.4.c	Agriculture/Forestry/Fisheries	1	–	2	1	3	1	1	–	–	–	1	–	–	–	–	–	–	–	–	–
Fuel consumed by all other sectors.		Assumed ±3% for all fuels as default value																			

TABLE A7-4: Sample Input Parameter Uncertainty Estimates Obtained from Expert Elicitation and Source Reference Research — Emission Factor Data for Stationary Fuel Combustion (ICF, 2004)

Source/Sub-Source Category	CO_2 Emission Factors	Probability Distribution	Uncertainty Range, Relative to 2001 Inventory Estimate		Confidence Interval	Data Source
	2001 Inventory Estimate		Low (%)	High (%)	(%)	
Coal	g/kg					
Lignite[1]	1420.22	Normal	-6	4	95	J. Gienow and O. Bussler, SaskPower
Anthracite[2]	2390.00	Normal	-5	5	95	Assumed
U.S. Bituminous[3]	2387.08	Normal	-3	3	95	McCann (2000)
Canadian Bituminous[3]	1973.13	Normal	-3	3	95	McCann (2000)
Sub-Bituminous[3]	1747.44	Normal	-3	3	95	McCann (2000)
Coke[2]	2480.00	Normal	-5	5	90	Assumed
Coke Oven Gas[2]	1600.00	Normal	-10	10	90	Assumed
Natural Gas	g/m^3					
Non-Energy	1266.97	Normal	-5	5	95	Assumed
Interprovincial[4]	1891.00	Normal	-3	3	95	McCann (2000)
Petroleum Refineries for Hydrogen[4]	1892.00	Normal	-3	3	95	McCann (2000)
Liquid	g/L					
Petroleum Coke	4200.00	Normal	-37	-25	95	McCann (2000)
Propane (Non-Energy Use)	303.00	Normal	-5	5	95	Assumed
Butane (Non-Energy Use)	349.00	Normal	-5	5	95	Assumed
Ethane (Non-Energy Use)	197.00	Normal	-5	5	95	Assumed
Petrochemical Feedstocks[5]	2500.00	Normal	-15	15	90	Assumed
Naphthas	2500.00	Normal	-10	10	95	Assumed
Lubricants[5]	2820.00	Normal	-10	10	90	Assumed
Other Products[5]	1835.00	Normal	-20	20	90	Assumed

Notes:

1 Emission factor range for Saskatchewan for energy use applied.

2 Same as for energy use.

3 These uncertainty ranges may be different from those used for energy use, as energy use emission factors were provincial.

4 Same as for energy use — natural gas in industry.

5 The uncertainty around the emission factor is assumed to be larger, as petrochemical feedstock is not a unique product, but compares general products. Hence, a 90% confidence interval is assumed.

A7.4.3 LEVEL OF AGGREGATION ADOPTED FOR UNCERTAINTY ANALYSIS

Theoretically, the ideal level of disaggregation for an uncertainty analysis should be the level at which the inventory estimation was performed, if the uncertainty input data can be reliably obtained for the variables at that level of disaggregation. However, from a practical implementation perspective, the appropriate level of disaggregation is also determined by budget and time constraints.

In this study, for each source category, the appropriate level of disaggregation was determined in consultation between the NIR team and the consultant. The uncertainty analysis for each key source category was generally conducted at the level at which it was believed that the uncertainty data associated with the inventory input variables could be obtained reliably. Table A7-5 reports the level of disaggregation adopted for performing the uncertainty analysis under this project. For identification of key categories among the categories shown in this table, the readers should refer to Tables A7-6 to A7-16 at the end of the annex (key sources are indicated by the symbol KS).

TABLE A7-5: Level of Aggregation Adopted for the Uncertainty Analysis, by Key Source Category (2001 inventory submitted in 2003)[1]

Source Category	IPCC Source Category	Direct GHG	Criteria for Identification[2]	Level of Aggregation
1-A-1-a	Fuel Combustion – Public Electricity and Heat Production	CO_2	Level, Trend, Quality	Provincial level for coal and national level for others
1-A-1-b	Fuel Combustion – Petroleum Refining	CO_2	Level, Trend, Quality	Provincial level for coal (coal is not used as refinery fuel) and national level for others
1-A-1-c	Fuel Combustion – Manufacture of Solid Fuels and Other Energy Industries	CO_2	Level, Trend, Quality	Provincial level for coal and national level for others
1-A-2	Fuel Combustion – Manufacturing Industries and Construction	CO_2	Level, Trend	Provincial level for coal and national level for others
1-A-3-a	Fuel Combustion – Civil Aviation	CO_2	Level	National, by fuel type
1-A-3-b	Fuel Combustion – Road Transportation	CO_2	Level, Trend, Quality	National, by vehicle category and fuel type
1-A-3-b	Fuel Combustion – Road Transportation	N_2O	Level, Trend, Quality	National, by vehicle category and fuel type
1-A-3-c	Fuel Combustion – Railways	CO_2	Level, Trend	National, by fuel type
1-A-3-e	Fuel Combustion – Other Transport	CO_2	Level	National, by fuel type
1-A-3-f	Fuel Combustion – Pipeline Transport	CO_2	Level, Trend, Quality	National, by fuel type
1-A-4	Fuel Combustion – Other Sectors	CO_2	Level, Trend	Provincial level for coal and national level for others
1-B-1-a	Fugitive Emissions – Coal Mining	CH_4	Level	National, by mine type
1-B-2-(a+b)	Fugitive Emissions – Oil and Natural Gas	CH_4	Level, Trend, Quality	National, by economic activity
1-B-2-c	Fugitive Emissions – Oil and Natural Gas – Venting and Flaring	CO_2	Level, Trend, Quality	National
1-B-2-c	Fugitive Emissions – Oil and Natural Gas – Venting and Flaring	CH_4	Quality	National
2-A-1	Industrial Processes – Cement Production	CO_2	Level, Quality	National
2-B-1	Industrial Processes – Ammonia Production	CO_2	Level	National
2-B-3	Industrial Processes – Adipic Acid Production	N_2O	Level, Trend, Quality	National
2-C-1	Industrial Processes – Iron and Steel Production	CO_2	Level	National
2-C-3	Industrial Processes – Aluminium Production	PFCs	Level, Quality	National, by technology type
2-C-4	Industrial Processes – Aluminium and Magnesium Production	SF_6	Level, Quality	National
2-F	Industrial Processes – Other (Undifferentiated Production)	CO_2	Level	National, by feedstock fuel type
4-A	Agriculture – Enteric Fermentation	CH_4	Level	National, by cattle type
4-B	Agriculture – Manure Management	CH_4	Level	National, by cattle type
4-D	Agriculture – Agricultural Soils	N_2O	Level	National with subsector details
6-A	Waste – Solid Waste Disposal on Land	CH_4	Level, Quality	National, by waste category

Notes:

1 This table was adapted based on Table A1-1 of the 2001 NIR.

2 Level, trend, and quality refer to the source category being a key source category based on level, trend, and quality.

In the next section, the uncertainty associated with the 2003 GHG inventory (submitted in 2005) will be discussed.

A7.5 ANALYSIS OF RESULTS

A7.5.1 SECTOR UNCERTAINTY IN GHG INVENTORY 2003

Canada has adopted Table 6.2 of IPCC (2000) for presenting its 2003 GHG inventory uncertainty estimates, as shown in Tables A7-6 to A7-16 provided at the end of this annex. For the trend uncertainty, the values shown in the tables provide a picture of trend uncertainty in 2001 and are not deemed to be representative of the trend uncertainty for the 2003 inventory. To emphasize this distinction, the trend values of 2001 have been included in an additional column (i.e., additional to IPCC 2000 Table 6.2) and immediately before the trend uncertainty ranges of 2001. The 2003 trend uncertainty is currently not available.

The tables provide source category, followed by the inventory estimates for 1990 baseline inventory year and for 2003 current inventory year, followed by the level uncertainty range in percentage of the inventory estimate for 2003. Values reflecting the contribution of the uncertainty in the source category to the overall uncertainty were not available at the time of this NIR (they will be added in the next NIR).

Highlights of the results obtained from analysis of uncertainty for various source sectors are presented below, along with a description of any changes in the activity data and/or emission factors that have occurred to some categories since the study of inventory uncertainty for 2001. For details of findings, reference should be made to the uncertainty sections within Chapters 3–8.

A7.5.1.1 Energy Sector — Stationary Combustion

Detailed analysis of uncertainty is provided in sections 3.1.1, 3.1.2, and 3.1.4 of Chapter 3. The overall uncertainty for CO_2 is found to have a range of -4% to 1%. The highest uncertainty range for CO_2 from major fuel types used in this subsector relates to liquid fuels (-15% to 2%). Estimates for uncertainty ranges for CH_4 and N_2O emissions in this subsector are -24% to +700% and -11% to +650%, respectively.

A7.5.1.2 Energy Sector — Transport

The uncertainty range for CO_2 estimates from transport, including road, aviation, and marine mobile sources, follows closely the values quoted for stationary combustion (-4% to 0% in this case). This is understandable, since CO_2 estimates' uncertainty directly follows the uncertainty existing in the fuel quantities consumed. Uncertainties for CH_4 and N_2O are in the ranges of -24% to +700% and -28% to +410%, respectively.

The picture of uncertainty for the categories in this subsector has generally remained the same, except for CO_2 emissions from domestic civil aviation, for which a new estimation method has been adopted. The uncertainties provided by the ICF (2004) study for this subsector are no longer applicable and need to be reassessed.

A7.5.1.3 Energy Sector — Fugitive Emissions

This subsector includes CH_4 and CO_2 fugitive emissions occurring in the coal mining and oil and gas industry. It includes emissions associated with leaks, venting, and flaring in the oil and gas operations, as well as in coal mining. The uncertainty ranges for emissions from venting and flaring activities in the oil and gas industry are -35% to -13% for CO_2 and -93% to -89% for CH_4.

The uncertainty range for fugitive emissions from the oil and gas sector is -35% to -13%. This estimate will be improved by the adoption of updated inventory methodology and activity data for the subsector, as obtained from the studies performed in 2004.

A7.5.1.4 Industrial Processes

CO_2 is the primary GHG associated with this sector and is emitted mostly as a result of process emissions in the mineral and metal categories (cement, lime, and iron and steel). The total CO_2 eq uncertainty estimate for this sector is -7% to +5%. The CO_2-only uncertainty is shown as +2% to +19%, which is a higher range than that for stationary and mobile combustion. This is primarily driven by the emission and activity data uncertainty in mineral processing.

The 2001 PFC emissions from aluminium smelting were found to demonstrate both model and parameter types of uncertainty. The uncertainty estimate for PFC emissions in the 2001 inventory are estimated at -70% to -60%. The method of estimation was based on the production levels (activity data) and production-based emission factors. Both input parameters used here were found to possess significant systematic uncertainties. The method of estimating emissions of PFCs from aluminium smelting have changed since 2001 (now a Tier 3 method is used for estimates of 2003). Hence, the uncertainty estimates of 2001 are no longer applicable for this source category. Canada plans to obtain new uncertainty estimates for this source category through expert elicitation.

A7.5.1.5 Agriculture

While certain changes to methods and factors have been adopted in the 2005 submission for a number of categories, it is assumed that the uncertainty ranges for those source categories are still reasonably valid and hence that the effect of changes on the overall inventory uncertainty is minimal.

A7.5.1.6 Waste Sector

Emissions evaluated for this sector include CH_4 emissions from solid waste disposal on land, CH_4 and N_2O emissions from wastewater handling, and CO_2, CH_4, and N_2O emissions from waste incineration.

A7.5.1.7 Waste Sector — Solid Waste Disposal on Land

The uncertainty associated with CH_4 emissions from the combined municipal and wood waste landfills was estimated to be in the range of -35% to 40%. The uncertainty is mainly due to a difference of opinion, presented during the expert elicitation process, on the values of the CH_4 generation potential and the CH_4 rate constant used in the Scholl Canyon model for the MSW landfill CH_4 generation estimates. Due to the limited information available on these parameters for Canadian conditions, this uncertainty is expected to be reduced based upon a study being developed to provide more accurate country-specific values for these model parameters.

A7.5.1.8 Waste Sector — Wastewater Handling

N_2O emissions were responsible for approximately 71% of the total emissions from this subsector. The overall level uncertainty associated with the Wastewater Handling subsector was estimated to be in the range of -40% to 55%. Uncertainties for CH_4 and N_2O emissions were -40% to 45% and -60% to 65%, respectively.

A7.5.1.9 Waste Sector — Waste Incineration

Overall uncertainty associated with the Waste Incineration source category was estimated to be in the range of -12% to 65%. CO_2 contributed roughly 81% of the total emissions from this subsector. The uncertainties associated with CO_2, CH_4, and N_2O emissions were -3% to 85%, -60% to 60%, and -80% to 85%, respectively.

A7.5.2 OVERALL UNCERTAINTY IN GHG INVENTORY 2003

Table A7-1 shows the overall level uncertainty picture for Canada's GHG inventory 2003 for each component GHG and for the overall inventory in CO_2 eq. with and without the incorporation of the uncertainty associated with the GWP of the component gases. Again, it is assumed that the overall uncertainty picture for the 2003 inventory is similar to the picture in 2001 for level uncertainties, as only two years have passed since the 2001 inventory, and the methods and activity data for the majority of the categories have remained unchanged.

Canada's GHG inventory level uncertainty currently falls within a range of -3% to +6% for all GHGs combined without consideration of the uncertainty within the GWPs. With GWP uncertainty considered, the overall uncertainty falls within a range of -5% to 10%. In regards to the particular GHGs, N_2O exhibits the highest uncertainty range in the national inventory, with a range of -8% to 80%, followed by HFCs, with a range of -22% to 60%. CO_2 exhibits an uncertainty of -4% to 0%. The overall Canadian inventory uncertainty estimate falls within the range of the uncertainties reported by other Annex I countries.

The use of IPCC default uncertainty ranges in certain categories (e.g., uncertainty associated with the national cement production, with a value of 35%) is believed to have generated a larger uncertainty range for the overall inventory. In the coming years, the overall uncertainty estimates should be improved further once national uncertainty ranges for certain variables are obtained. Sensitivity of the overall inventory uncertainty to the uncertainties existing in the component categories and the sensitivity of each category uncertainty to the uncertainty existing in its input parameters represent important information that the national inventory agencies should use to improve the uncertainty. These sensitivities are currently being assessed for the Canadian inventory and will be discussed in the next national GHG inventory submission.

TABLE A7-6: Tier 2 Uncertainty Reporting — CO_2 Energy (Stationary Combustion)

IPCC Source Category	Gas	Base Year Emissions (1990)	Year t Emissions (2003)	Uncertainty in Year t Emissions as % of Emissions in the Category		Uncertainty Introduced on National Total in Year t	% Change in Emissions between Year t and Base Year	% Change in Emissions between 2001 and 1990 as per ICF Study	Range of Likely % Change between 2001 and 1990 as per ICF Study		Comments
		Gg CO_2 eq	*Gg CO_2 eq*	*% Below (2.5th percentile)*	*% Above (97.5th percentile)*	%	%	%	*Lower % (2.5th percentile)*	*Upper % (97.5th percentile)*	Method changes or any other factors that woul alter the estimated uncertainty from 2001
1.A. Fuel Combustion	CO_2	276 060.3	354 921.3	-4	1	–	29	21	20	23	–
Liquid Fuels	CO_2	64 901.6	70 501.7	-15	2	–	9	–	–	–	–
Solid Fuels	CO_2	94 556.4	123 892.8	-3	3	–	31	–	–	–	–
Gaseous Fuels	CO_2	116 602.3	160 526.8	-2	2	–	38	–	–	–	–
1.A.1. Energy Industries	CO_2	144 276.6	205 623.8	-6	2	–	43	40	35	45	–
Liquid Fuels	CO_2	28 542.6	35 944.2	-24	5	–	26	–	–	–	–
Solid Fuels	CO_2	85 581.8	114 774.4	-3	4	–	34	–	–	–	–
Gaseous Fuels	CO_2	30 152.2	54 905.2	-5	5	–	82	–	–	–	–
1.A.1.a. Public Electricity and Heat Production (KS)	CO_2	94 744.6	137 106.8	-3	3	–	45	45	40	50	–
1.A.1.a.i Electricity Generation – Utilities	CO_2	91 847.6	127 008.3	-3	3	–	38	–	–	–	–
1.A.1.a.ii Electricity Generation – Industry	CO_2	2 207.2	4 566.0	-8	3	–	107	–	–	–	–
1.A.1.a.iii Heat/Steam Generation	CO_2	689.8	5 532.6	-2	2	–	702	–	–	–	–
1.A.1.b. Petroleum Refining (Upstream & Downstream Oil and Gas Industries) (KS)	CO_2	25 976.7	33 675.3	-35	7	–	30	11	7	10	–
1.A.1.c. Manufacture of Solid Fuels and Other Energy Industries (KS)	CO_2	23 555.3	34 841.7	-8	8	–	48	50	45	60	–
1.A.2. Manufacturing Industries and Construction (KS)	CO_2	62 368.4	65 495.3	-3	2	–	5	-4	-5	-2	–
Liquid Fuels	CO_2	14 120.4	11 139.2	-9	1	–	-21	–	–	–	–
Solid Fuels	CO_2	8 783.2	9 027.1	-4	5	–	3	–	–	–	–
Gaseous Fuels	CO_2	39 464.8	45 328.9	-3	3	–	15	–	–	–	–
1.A.2.a. Iron and Steel	CO_2	6 423.6	6 358.4	-5	5	–	-1	-9	-15	-4	–
1.A.2.b. Non-Ferrous Metals	CO_2	3 209.8	3 185.8	-6	-1	–	-1	8	18	22	–
1.A.2.c. Chemicals	CO_2	7 056.7	5 704.0	-3	2	–	-19	-9	-10	-8	–
1.A.2.d. Pulp, Paper and Print	CO_2	13 367.5	8 820.5	-4	4	–	-34	-29	-29	-27	–
1.A.2.e. Food Processing, Beverages and Tobacco	CO_2	IE	IE	–	–	–	–	–	–	–	Emissions from Food Processing, Beverag and Tobacco is included in Other Manufacturing (1.A.2.f.iv)
1.A.2.f. Other	CO_2	32 310.7	41 426.6	-3	2	–	28	8	4	9	–
1.A.2.f.i Cement	CO_2	3 569.9	4 183.6	9	16	–	17	-3	8	16	–
1.A.2.f.ii Mining	CO_2	6 156.8	15 561.4	-3	3	–	153	65	60	70	–
1.A.2.f.iii Construction	CO_2	1 861.4	1 290.5	-3	2	–	-31	-45	-50	-45	–
1.A.2.f.iv Other Manufacturing	CO_2	20 722.6	20 391.1	-6	1	–	-2	-3	-11	-4	–
1.A.4. Other Sectors (KS)	CO_2	69 415.3	83 802.3	-3	2	–	21	7	6	9	–
Liquid Fuels	CO_2	22 238.5	23 418.3	-5	1	–	5	–	–	–	–
Solid Fuels	CO_2	191.5	91.4	-5	1	–	-52	–	–	–	–
Gaseous Fuels	CO_2	46 985.3	60 292.6	-3	3	–	28	–	–	–	–
1.A.4.a. Commercial/Institutional	CO_2	25 677.1	38 762.8	-3	3	–	51	27	23	30	–
1.A.4.b. Residential	CO_2	41 335.0	42 843.5	-3	2	–	4	-5	-6	-3	–
1.A.4.c. Agriculture/Forestry/Fisheries	CO_2	2 403.2	2 196.0	-3	1	–	-9	-9	-9	-7	–

Notes:

(KS) = Key Source; IE = included elsewhere

TABLE A7-7: Tier 2 Uncertainty Reporting — CH_4 Energy (Stationary Combustion)

IPCC Source Category	Gas	Base Year Emissions (1990)	Year t Emissions (2003)	Uncertainty in Year t Emissions as % of Emissions in the Category		Uncertainty Introduced on National Total in Year t	% Change in Emissions between Year t and Base Year	% Change in Emissions between 2001 and 1990 as per ICF Study	Range of Likely % Change between 2001 and 1990 as per ICF Study		Comments
		Gg CO_2 eq	Gg CO_2 eq	% Below (2.5th percentile)	% Above (97.5th percentile)	%	%	%	Lower % (2.5th percentile)	Upper % (97.5th percentile)	Method changes or any other factors that would alter the estimated uncertainty from 2001
1.A. Fuel Combustion	CH_4	7693.3	4548.6	-24	700	–	-41	19	-2	45	See Note 1
Liquid Fuels	CH_4	3857.9	21.3	1	490	–	-99	–	–	–	See Note 2
Solid Fuels	CH_4	37.5	44.7	-24	210	–	19	–	–	–	See Note 2
Gaseous Fuels	CH_4	1685.4	2498.0	0	230	–	48	–	–	–	See Note 2
Biomass	Ch_4	2112.4	1984.7	-95	1500	–	-6	–	–	–	See Note 1
1.A.1. Energy Industries	CH_4	1681.2	2496.2	1	230	–	48	50	45	55	See Note 1
Liquid Fuels	CH_4	7.4	7.8	14	850	–	4	–	–	–	See Note 2
Solid Fuels	CH_4	23.9	33.9	-18	19	–	42	–	–	–	See Note 2
Gaseous Fuels	CH_4	1649.9	2454.6	0	230	–	49	–	–	–	Need to reassess the uncertainty assumption for non-marketable natural gas emission factor – Refer to Chapter 3 of the NIR for additional details
Biomass	CH_4	–	–	–	–	–	–	–	–	–	–
1.A.1.a. Public Electricity and Heat Production (KS)	CH_4	38.3	106.4	-20	40	–	178	170	100	200	See Note 2
1.A.1.a.i Electricity Generation – Utilities	CH_4	36.7	102.3	-23	35	–	178	–	–	–	See Note 2
1.A.1.a.ii Electricity Generation – Industry	CH_4	1.1	1.9	-28	220	–	70	–	–	–	See Note 2
1.A.1.a.iii Heat/Steam Generation	CH_4	0.4	2.1	24	1900	–	454	–	–	–	See Note 2
1.A.1.b. Petroleum Refining (Upstream & Downstream Oil and Gas Industries) (KS)	CH_4	8.8	10.6	-50	900	–	20	19	-26	50	See Note 2
1.A.1.c. Manufacture of Solid Fuels and Other Energy Industries (KS)	CH_4	1634.1	2379.3	0	240	–	46	50	40	55	See Note 2
1.A.2. Manufacturing Industries and Construction (KS)	CH_4	59.2	68.4	-35	380	–	15	1	-35	45	See Note 1
Liquid Fuels	CH_4	10.2	7.5	-18	230	–	-26	–	–	–	See Note 2
Solid Fuels	CH_4	5.3	5.5	-70	350	–	3	–	–	–	See Note 2
Gaseous Fuels	CH_4	16.2	18.6	-40	40	–	15	–	–	–	See Note 2
Biomass	CH_4	27.5	36.7	-95	1400	–	34	–	–	–	See Note 2
1.A.2.a. Iron and Steel	CH_4	5.1	4.9	-70	320	–	-3	-6	-90	535	See Note 2
1.A.2.b. Non-Ferrous Metals	CH_4	1.4	1.5	-19	95	–	3	19	10	27	See Note 2
1.A.2.c. Chemicals	CH_4	3.0	2.5	-35	40	–	-19	-7	-9	-1	See Note 2
1.A.2.d. Pulp, Paper and Print	CH_4	35.9	42.2	-60	900	–	18	0	-28	35	See Note 2
1.A.2.e. Food Processing, Beverages and Tobacco	CH_4	IE	IE	–	–	–	–	–	–	–	Emissions from Food Processing, Beverages and Tobacco are included in Other Manufacturing (1.A.2.f.iv)
1.A.2.f. Other	CH_4	13.8	17.3	-28	120	–	26	3	0	21	See Note 2
1.A.2.f.i Cement	CH_4	1.4	1.7	-35	500	–	17	6	-7	27	See Note 2
1.A.2.f.ii Mining	CH_4	2.7	6.6	-28	160	–	147	60	18	155	See Note 2
1.A.2.f.iii Construction	CH_4	0.7	0.5	-35	190	–	-27	-45	-60	-40	See Note 2
1.A.2.f.iv Other Manufacturing	CH_4	9.0	8.6	-30	70	–	-5	-11	-14	5	See Note 2
1.A.4. Other Sectors (KS)	CH_4	2117.5	1984.1	-90	1500	–	-6	-6	-13	6	See Note 1
Liquid Fuels	CH_4	4.9	6.0	-40	280	–	23	–	–	–	See Note 2
Solid Fuels	CH_4	8.3	5.3	-75	1100	–	-37	–	–	–	See Note 2
Gaseous Fuels	CH_4	19.3	24.8	-40	40	–	28	–	–	–	See Note 2
Biomass	CH_4	2085.0	1948.0	-95	1500	–	-7	–	–	–	See Note 2
1.A.4.a. Commercial/Institutional	CH_4	10.1	14.4	-28	160	–	43	30	30	185	See Note 2
1.A.4.b. Residential	CH_4	2106.7	1968.9	-90	1500	–	-7	-6	-15	3	See Note 2
1.A.4.c. Agriculture/Forestry/Fisheries	CH_4	0.8	0.8	-28	230	–	2	0	-4	21	See Note 2

Notes:

1 Refer to Chapter 3 of the NIR for a discussion of the uncertainty associated with CH_4 and N_2O emission factors. The uncertainty range as presented does not include the uncertainty associated with the GWP for the corresponding emission values.

2 The uncertainty range as presented does not include the uncertainty associated with the GWP for the corresponding emission values.

(KS) = Key Source; IE = included elsewhere

TABLE A7-8: Tier 2 Uncertainty Reporting — N_2O Energy (Stationary Combustion)

IPCC Source Category	Gas	Base Year Emissions (1990)	Year t Emissions (2003)	Uncertainty in Year t Emissions as % of Emissions in the Category		Uncertainty Introduced on National Total in Year t	% Change in Emissions between Year t and Base Year	% Change in Emissions between 2001 and 1990 as per ICF Study	Range of Likely % Change between 2001 and 1990 as per ICF Study		Comments
		Gg CO_2 eq	Gg CO_2 eq	% Below (2.5th percentile)	% Above (97.5th percentile)	%	%	%	Lower % (2.5th percentile)	Upper % (97.5th percentile)	Method changes or any other factors that woul alter the estimated uncertainty from 2001
1.A. Fuel Combustion	N_2O	2 145.1	2 725.8	-11	650	–	27	20	-45	190	See Note 1
Liquid Fuels	N_2O	379.8	468.4	-12	800	–	23	–	–	–	See Note 2
Solid Fuels	N_2O	509.8	657.1	-60	1 000	–	29	–	–	–	See Note 2
Gaseous Fuels	N_2O	749.6	1 062.0	-65	950	–	42	–	–	–	See Note 2
Biomass		506.0	538.2	-85	1 200	–	6	–	–	–	See Note 2
1.A.1. Energy Industries	N_2O	903.5	1 315.4	-23	800	–	46	40	-65	490	See Note 1
Liquid Fuels	N_2O	184.1	244.3	0	1 100	–	33	–	–	–	See Note 2
Solid Fuels	N_2O	453.0	600.3	-70	1 100	–	33	–	–	–	See Note 2
Gaseous Fuels	–	266.5	470.8	-80	1 200	–	77	–	–	–	See Note 2
Biomass	N_2O	–	–	–	–	–	–	–	–	–	–
1.A.1.a. Public Electricity and Heat Production (KS)	N_2O	549.8	843.3	-35	900	–	53	40	-75	950	See Note 2
1.A.1.a.i Electricity Generation – Utilities	N_2O	530.9	727.6	-50	900	–	37	–	–	–	See Note 2
1.A.1.a.ii Electricity Generation – Industry	N_2O	15.0	26.6	-70	1 000	–	77	–	–	–	See Note 2
1.A.1.a.iii Heat/Steam Generation	N_2O	3.9	89.1	170	12 000	–	2 171	–	–	–	See Note 2
1.A.1.b. Petroleum Refining (Upstream & Downstream Oil and Gas Industries) (KS)	N_2O	130.2	146.2	-28	1 000	–	12	5	-40	40	See Note 2
1.A.1.c. Manufacture of Solid Fuels and Other Energy Industries (KS)	N_2O	223.5	325.9	-90	1 500	–	46	50	35	80	See Note 2
1.A.2. Manufacturing Industries and Construction (KS)	N_2O	540.1	615.3	-55	850	–	14	3	-35	65	See Note 1
Liquid Fuels	N_2O	108.1	96.9	-45	650	–	-10	–	–	–	See Note 2
Solid Fuels	N_2O	56.2	56.4	-75	550	–	0	–	–	–	See Note 2
Gaseous Fuels	N_2O	213.5	245.2	-95	1 500	–	15	–	–	–	See Note 2
Biomass	N_2O	162.3	216.8	-95	1 500	–	34	–	–	–	See Note 2
1.A.2.a. Iron and Steel	N_2O	58.2	57.1	-85	650	–	-2	-6	-90	640	See Note 2
1.A.2.b. Non-Ferrous Metals	N_2O	14.6	15.1	-55	850	–	4	21	-60	235	See Note 2
1.A.2.c. Chemicals	N_2O	38.5	31.1	-85	1 300	–	-19	-9	-11	9	See Note 2
1.A.2.d. Pulp, Paper and Print	N_2O	241.0	268.7	-60	900	–	11	-6	-29	30	See Note 2
1.A.2.e. Food Processing, Beverages and Tobacco	N_2O	IE	IE	–	–	–	–	–	–	–	Emissions from Food Processing, Beverages and Tobacco are included in Other Manufacturing (1.A.2.f.iv)
1.A.2.f. Other	N_2O	187.7	243.3	-65	1 000	–	30	11	-25	65	See Note 2
1.A.2.f.i Cement	N_2O	14.1	14.8	-55	850	–	5	2	-80	540	See Note 2
1.A.2.f.ii Mining	N_2O	36.7	103.8	-70	1 000	–	183	110	3	280	See Note 2
1.A.2.f.iii Construction	N_2O	16.5	8.8	-75	1 100	–	-47	-55	-65	-35	See Note 2
1.A.2.f.iv Other Manufacturing	N_2O	120.5	116.0	-75	1 200	–	-4	-0	-30	17	See Note 2
1.A.4. Other Sectors (KS)	N_2O	701.4	795.1	-65	1 000	–	13	6	-13	40	See Note 1
Liquid Fuels	N_2O	87.6	127.3	-35	850	–	45	–	–	–	See Note 2
Solid Fuels	N_2O	0.6	0.4	-75	1 100	–	-37	–	–	–	See Note 2
Gaseous Fuels	N_2O	269.6	345.9	-95	1 400	–	28	–	–	–	See Note 2
Biomass	N_2O	343.6	321.5	-95	1 400	–	-6	–	–	–	See Note 2
1.A.4.a. Commercial/Institutional	N_2O	153.1	244.4	-70	1 000	–	60	40	22	110	See Note 2
1.A.4.b. Residential	N_2O	531.7	533.2	-75	1 100	–	0	-3	-24	10	See Note 2
1.A.4.c. Agriculture/Forestry/Fisheries	N_2O	16.6	17.5	-70	1 000	–	5	5	-12	19	See Note 2

Notes:

1 Refer to Chapter 3 of the NIR for a discussion of the uncertainty associated with CH_4 and N_2O emission factors. The uncertainty range as presented does not include the uncertainty associated with the GWP for the corresponding emission values.

2 The uncertainty range as presented does not include the uncertainty associated with the GWP for the corresponding emission values.

(KS) = Key Source; IE = included elsewhere

TABLE A7-9: Tier 2 Uncertainty Reporting — CO_2 Energy (Transport)

IPCC Source Category	Gas	Base Year Emissions (1990)	Year t Emissions (2003)	Uncertainty in Year t Emissions as % of Emissions in the Category		Uncertainty Introduced on National Total in Year t	% Change in Emissions between Year t and Base Year	% Change in Emissions between 2001 and 1990 as per ICF Study	Range of Likely % Change between 2001 and 1990 as per ICF Study		Comments
		Gg CO_2 eq	Gg CO_2 eq	% Below (2.5th percentile)	% Above (97.5th percentile)	%	%	%	Lower % (2.5th percentile)	Upper % (97.5th percentile)	Method changes or any other factors that would alter the estimated uncertainty from 2001
1.A.3. Transport	CO_2	141 931.5	179 147.4	–	–	–	26	–	–	–	–
Total Mobile Sources (Total Transport excluding Pipelines)	CO_2	135 226.5	170 301.8	-4	0	–	26	20	18	23	–
Total Non.Rail Surface Transport Vehicles (On-Road & Off-Road)	CO_2	117 963.2	152 204.5	-4	0	–	29	23	20	26	–
1.A.3.a. Civil Aviation (KS)	CO_2	6 215.7	7 001.2	–	–	–	13	13	12	15	Aviation methodology has been greatly enhanced. Fuel sold to Canadian airlines has now been allocated to either international or domestic use based upon supplemental t-km activity data.
1.A.3.b. Road Transportation (KS)	CO_2	102 877.5	134 556.8	-8	-3	–	31	24	20	28	A new MGEM model was used this year, which has rebuilt the method in a database. The relationships are now uniform through the time series, and the structure allows for both more data resolution and future relationship enhancement for activity data.
On-Road Gasoline Vehicles (Cars + Trucks + Heavy-Duty + Motorcycles)	CO_2	75 195.0	90 695.2	-7	-3	–	21	16	12	19	See Note 1
On-Road Diesel Vehicles (Cars + Trucks + Heavy-Duty)	CO_2	25 521.4	43 081.6	-13	-1	–	69	55	45	70	See Note 1
On-Road Natural Gas Vehicles	CO_2	83.8	86.6	-4	4	–	3	40	35	45	–
On-Road Propane Vehicles	CO_2	2 077.4	693.3	-2	2		-67	-55	-55	-50	–
1.A.3.c. Railways (KS)	CO_2	6 315.0	5 261.8	-5	3	–	-17	-8	-13	-5	–
1.A.3.d. Navigation (KS)	CO_2	4 732.6	5 834.3	-3	3	–	23	9	6	13	–
1.A.3.e. Other Transportation (KS)	CO_2	21 790.7	26 493.4	–	–	–	22	–	–	–	–
1.A.3.e.i Off-Road	CO_2	15 085.7	17 647.7	4	45	–	17	17	-5	50	In unison with the MGEM model update, Off-Road values would be commensurately improved. Some data previously truncated are now carried at full resolution.
Off-Road – Gasoline	CO_2	4 908.8	4 244.8	-1	110	–	-14	–	–	–	–
Off-Road – Diesel	CO_2	10 176.9	13 402.9	-5	35	–	32	–	–	–	–
1.A.3.e.ii Pipeline (Transport) (KS)	CO_2	6 704.9	8 845.6	-3	3		32	–	–	–	–
Liquid Fuels	CO_2	43.1	56.0	-6	3		30	–	–	–	–
Gaseous Fuels	CO_2	6 661.8	8 789.7	-3	3		32	–	–	–	–

Notes:

1 It is the practitioner responsible for the Transportation sector estimates who feels that the uncertainty attributed to activity data, whether fuel consumption or, more specifically, vehicle populations, is flawed in its construction and solicitation. This, however, has minimal effects in a fuel-constrained model.

(KS) = Key Source

TABLE A7-10: Tier 2 Uncertainty Reporting — CH_4 Energy (Transport)

IPCC Source Category	Gas	Base Year Emissions (1990)	Year t Emissions (2003)	Uncertainty in Year t Emissions as % of Emissions in the Category		Uncertainty Introduced on National Total in Year t	% Change in Emissions between Year t and Base Year	% Change in Emissions between 2001 and 1990 as per ICF Study	Range of Likely % Change between 2001 and 1990 as per ICF Study		Comments
		Gg CO_2 eq	*Gg CO_2 eq*	*% Below (2.5th percentile)*	*% Above (97.5th percentile)*	%	%	%	*Lower % (2.5th percentile)*	*Upper % (97.5th percentile)*	Method changes or any other factors that would alter the estimated uncertainty from 2001
1.A.3. Transport	CH_4	640.6	583.3	–	–	–	-9	–	–	–	–
Total Mobile Sources (Total Transport excluding Pipelines)	CH_4	499.95	397.74	-24	700	–	-20	-12	-25	23	–
Total Non.Rail Surface Transport Vehicles (On-Road & Off-Road)	CH_4	473.91	372.99	-29	700	–	-21	-13	-26	24	–
1.A.3.a. Civil Aviation (KS)	CH_4	11.38	8.83	–	–	–	-22	-12	-35	13	Aviation methodology has been greatly enhanced. Fuel sold to Canadian airlines has now been allocated to either international or domestic use based upon supplemental t-km activity data.
1.A.3.b. Road Transportation (KS)	CH_4	345.01	256.57	-19	18	–	-26	-17	-24	-8	A new MGEM model was used this year, which has rebuilt the method in a database. The relationships are now uniform through the time series, and the structure allows for both more data resolution and future relationship enhancement for activity data.
On-Road Gasoline Vehicles (Cars + Trucks + Heavy-Duty + Motorcycles)	CH_4	283.71	186.68	-22	16	–	-34	-25	-30	-18	See Note 1
On-Road Diesel Vehicles (Cars + Trucks + Heavy-Duty)	CH_4	25.71	43.68	-65	55	–	70	55	45	70	See Note 1
On-Road Natural Gas Vehicles	CH_4	20.47	21.16	-50	120	–	3	40	35	45	–
On-Road Propane Vehicles	CH_4	15.12	5.05	-50	120		-67	-55	-55	-50	–
1.A.3.c. Railways (KS)	CH_4	7.29	6.07	-60	60	–	-17	-8	-12	-4	–
1.A.3.d. Navigation (KS)	CH_4	7.38	9.85	-40	190	–	34	11	6	15	–
1.A.3.e. Other Transportation (KS)	CH_4	269.50	301.94	–	–	–	12	–	–	–	–
1.A.3.e.i Off-Road	CH_4	128.90	116.42	-80	2300	–	-10	-3	-35	60	In unison with the MGEM model update, Off-Road values would be commensurately improved. Some data previously truncated are now carried at full resolution.
Off-Road – Gasoline	CH_4	117.94	101.98	-90	2600	–	-14	–	–	–	–
Off-Road – Diesel	CH_4	10.96	14.43	-90	1700	–	32	–	–	–	–
1.A.3.e.ii Pipeline (Transport) (KS)	CH_4	140.61	185.52	–	–		32	–	–	–	–
Liquid Fuels	CH_4	0.04	0.06	–	–		30	–	–	–	–
Gaseous Fuels	CH_4	140.56	185.46	–	–		32	–	–	–	–

Notes:

1 It is the practitioner responsible for the Transportation sector estimates who feels that the uncertainty attributed to activity data, whether fuel consumption or, more specifically, vehicle populations, is flawed in its construction and solicitation. This, however, has minimal effects in a fuel-constrained model.

(KS) = Key Source

TABLE A7-11: Tier 2 Uncertainty Reporting — N_2O Energy (Transport)

IPCC Source Category	Gas	Base Year Emissions (1990)	Year t Emissions (2003)	Uncertainty in Year t Emissions as % of Emissions in the Category		Uncertainty Introduced on National Total in Year t	% Change in Emissions between Year t and Base Year	% Change in Emissions between 2001 and 1990 as per ICF Study	Range of Likely % Change between 2001 and 1990 as per ICF Study		Comments
		Gg CO_2 eq	*Gg CO_2 eq*	*% Below (2.5th percentile)*	*% Above (97.5th percentile)*	*%*	*%*	*%*	*Lower % (2.5th percentile)*	*Upper % (97.5th percentile)*	Method changes or any other factors that would alter the estimated uncertainty from 2001
1.A.3. Transport	N_2O	6293.5	8069.3	–	–	–	28	–	–	–	–
Total Mobile Sources (Total Transport excluding Pipelines)	N_2O	6236.91	7994.75	-28	410	–	28	-12	-25	23	–
Total Non-Rail Surface Transport Vehicles (On-Road & Off-Road)	N_2O	4950.07	6834.30	-35	390	–	38	-13	-26	24	–
1.A.3.a. Civil Aviation (KS)	N_2O	188.99	212.83	–	–	–	13	-12	-35	13	Aviation methodology has been greatly enhanced. Fuel sold to Canadian airlines has now been allocated to either international or domestic use based upon supplemental t-km activity data.
1.A.3.b. Road Transportation (KS)	N_2O	3646.65	5132.29	-35	35	–	41	-17	-24	-8	A new MGEM model was used this year, which has rebuilt the method in a database. The relationships are now uniform through the time series, and the structure allows for both more data resolution and future relationship enhancement for activity data.
On-Road Gasoline Vehicles (Cars + Trucks + Heavy-Duty + Motorcycles)	N_2O	3385.14	4715.88	-35	30	–	39	-25	-30	-18	See Note 1
On-Road Diesel Vehicles (Cars + Trucks + Heavy-Duty)	N_2O	248.66	411.55	-70	260	–	66	55	45	70	See Note 1
On-Road Natural Gas Vehicles	N_2O	0.82	0.85	-95	1400	–	3	40	35	45	–
On-Road Propane Vehicles	N_2O	12.02	4.01	-95	1500	–	-67	-55	-55	-50	–
1.A.3.c. Railways (KS)	N_2O	788.80	657.24	-95	1500	–	-17	-8	-12	-4	–
1.A.3.d. Navigation (KS)	N_2O	309.05	290.38	-90	1300	–	-6	11	6	15	–
1.A.3.e. Other Transportation (KS)	N_2O	1359.99	1776.60	–	–	–	31	–	–	–	–
1.A.3.e.i Off-Road	N_2O	1303.42	1702.02	-90	1800	–	31	-3	-35	60	In unison with the MGEM model update, Off-Road values would be commensurately improved. Some data previously truncated are now carried at full resolution.
Off-Road – Gasoline	N_2O	32.24	27.88	-90	2600	–	-14	–	–	–	–
Off-Road – Diesel	N_2O	1271.18	1674.14	-90	1700	–	32	–	–	–	–
1.A.3.e.ii Pipeline (Transport) (KS)	N_2O	56.56	74.59	–	–	–	32	–	–	–	–
Liquid Fuels	N_2O	1.96	2.54	–	–	–	30	–	–	–	–
Gaseous Fuels	N_2O	54.60	72.05	–	–	–	32	–	–	–	–

Notes:

1 It is the practitioner responsible for the Transportation sector estimates who feels that the uncertainty attributed to activity data, whether fuel consumption or, more specifically, vehicle populations, is flawed in its construction and solicitation. This, however, has minimal effects in a fuel-constrained model.

(KS) = Key Source

TABLE A7-12: Tier 2 Uncertainty Reporting — CO_2 Energy (Fugitives)

IPCC Source Category	Gas	Base Year Emissions (1990)	Year t Emissions (2003)	Uncertainty in Year t Emissions as % of Emissions in the Category		Uncertainty Introduced on National Total in Year t	% Change in Emissions between Year t and Base Year	% Change in Emissions between 2001 and 1990 as per ICF Study	Range of Likely % Change between 2001 and 1990 as per ICF Study		Comments
		Gg CO_2 eq	*Gg CO_2 eq*	*% Below (2.5th percentile)*	*% Above (97.5th percentile)*	%	%	%	*Lower % (2.5th percentile)*	*Upper % (97.5th percentile)*	Method changes or any other factors that would alter the estimated uncertainty from 2001
1.B. Fugitive Emissions from Coal Mining/ Handling and from Oil and Gas	CO_2	9 832.7	15 242.5	-35	-13	–	55	55	-3	45	ICF (2005)
1.B.1.a. Fugitive Emissions – Coal Mining	CO_2	–	–	–	–	–	–	–	–	–	–
1.B.2.(a+b) Fugitive Emissions – Oil and Natural Gas (KS)	CO_2	45.6	75.7	-35	-13	–	66	55	-3	45	ICF (2005)
1.B.2.a. Oil	CO_2	26.9	47.1	-60	-40	–	75	190	11	90	–
1.B.2.a.i Production	CO_2	26.8	47.0	-60	-40	–	76	–	–	–	–
1.B.2.a.ii Transport	CO_2	0.1	0.1	-35	35	–	10	–	–	–	–
1.B.2.b. Natural Gas	CO_2	18.7	28.6	25	55	–	53	55	35	85	–
1.B.2.b.i Production/Processing	CO_2	15.9	25.0	26	60	–	57	–	–	–	–
1.B.2.b.ii Transmission	CO_2	1.5	2.0	-5	70	–	32	–	–	–	–
1.B.2.b.iii Other Leakage	CO_2	1.3	1.6	-40	35	–	26	–	–	–	–
1.B.2.c. Fugitive Emissions – Oil and Natural Gas – Venting and Flaring (KS)	CO_2	9 787.0	15 166.7	-35	-13	–	55	55	-4	44	ICF (2005)
Venting	CO_2	4 499.3	7 784.5	-29	10	–	73	–	–	–	ICF (2005)
Flaring	CO_2	5 287.7	7 382.2	-50	-30	–	40	–	–	–	ICF (2005)

Note:

1 Overall uncertainty for Total GHG (CO2 eq) Fugitive Emissions (oil and gas, excluding coal) is -10% and 9%, as per the ICF (2005) study.

(KS) = Key Source

TABLE A7-13: Tier 2 Uncertainty Reporting — CH_4 Energy (Fugitives)

IPCC Source Category	Gas	Base Year Emissions (1990)	Year t Emissions (2003)	Uncertainty in Year t Emissions as % of Emissions in the Category		Uncertainty Introduced on National Total in Year t	% Change in Emissions between Year t and Base Year	% Change in Emissions between 2001 and 1990 as per ICF Study	Range of Likely % Change between 2001 and 1990 as per ICF Study		Comments
		Gg CO_2 eq	Gg CO_2 eq	% Below (2.5th percentile)	% Above (97.5th percentile)	%	%	%	Lower % (2.5th percentile)	Upper % (97.5th percentile)	Method changes or any other factors that would alter the estimated uncertainty from 2001
1.B. Fugitive Emissions from Coal Mining/Handling and from Oil and Gas	CH_4	28 095.5	38 728.8	-7	16	–	38	40	23	65	ICF (2005)
1.B.1.a. Fugitive Emissions – Coal Mining (KS)	CH_4	1 914.4	990.2	-30	130	–	-48	-50	-70	22	See Note 1; ICF (2005)
1.B.1.a.i Underground Mines	CH_4	1 207.4	310.3	-50	50	–	-74	–	–	–	See Note 1
1.B.1.a.ii Surface Mines	CH_4	707.0	679.9	-40	180	–	-4	–	–	–	See Note 1
1.B.2.(a+b) Fugitive Emissions – Oil and Natural Gas (KS)	CH_4	25 685.2	37 084.2	-7	15	–	44	45	28	75	ICF (2005)
1.B.2.a. Oil	CH_4	8 543.3	13 326.3	-29	13	–	56	65	29	150	–
1.B.2.a.i Production	CH_4	8 511.6	13 291.7	-29	13	–	56	–	–	–	See Note 1
1.B.2.a.ii Transport	CH_4	31.7	34.6	-35	35	–	9	–	–	–	See Note 1
1.B.2.b. Natural Gas	CH_4	17 141.9	23 757.9	1	28	–	39	40	19	70	ICF (2005)
1.B.2.b.i Production/Processing	CH_4	8 641.0	12 868.1	-9	21	–	49	–	–	–	See Note 1
1.B.2.b.ii Transmission	CH_4	4 298.4	5 672.1	-7	65	–	32	–	–	–	See Note 1
1.B.2.b.iii Distribution	CH_4	2 751.0	3 388.7	-6	70	–	23	–	–	–	See Note 1
1.B.2.b.iv Other Leakage	CH_4	1 451.5	1 829.1	-40	35	–	26	–	–	–	See Note 1
1.B.2.c. Fugitive Emissions – Oil and Natural Gas – Venting and Flaring (KS)	CH_4	495.9	654.4	-95	-90	–	32	35	-90	-85	ICF (2005)
Venting	CH_4	0.0	0.0	–	–	–	–	–	–	–	ICF (2005)
Flaring	CH_4	495.9	654.4	-95	-90	–	32	–	–	–	ICF (2005)

Notes:

1 The uncertainty range as presented does not include the uncertainty associated with the GWP for the corresponding emission values.

(KS) = Key Source

TABLE A7-14: Tier 2 Uncertainty Reporting — Industrial Process, Solvent and Other Product Use

IPCC Source Category	Gas	Base Year Emissions (1990)	Year t Emissions (2003)	Uncertainty in Year t Emissions as % of Emissions in the Category		Uncertainty Introduced on National Total in Year t	% Change in Emissions between Year t and Base Year	% Change in Emissions between 2001 and 1990 as per ICF Study	Range of Likely % Change between 2001 and 1990 as per ICF Study		Comments
		Gg CO_2 eq	*Gg CO_2 eq*	*% Below (2.5th percentile)*	*% Above (97.5th percentile)*	%	%	%	*Lower % (2.5th percentile)*	*Upper % (97.5th percentile)*	Method changes or any other factors that would alter the estimated uncertainty from 2001
2.A. Mineral Products	–	–	–	–	–	–	–	6	-28	55	–
2.A.1. Cement Production (KS)	CO_2	5 583.15	6 814.90	-35	35	–	22	11	-35	85	See Note 1
2.A.2. Lime Production (KS)	CO_2	1 748.95	1 642.61	-2	110	–	-6	-5	-45	65	See Note 1
2.A.3. Limestone and Dolomite Use (KS)	CO_2	370.92	157.52	-16	16	–	-58	-9	-15	-2	–
2.A.4. Soda Ash Use (KS)	CO_2	73.83	77.34	-26	29	–	5	-6	-35	30	See Note 1
2.B. Chemical Industry	–	–	–	–	–	–	–	18	-16	65	–
2.B.1. Ammonia Production (KS)	CO_2	5 007.51	6 169.35	-23	55	–	23	18	-16	65	–
2.B.2. Nitric Acid Production (KS)	N_2O	777	806	-15	16	–	4	2	-18	28	–
2.B.3. Adipic Acid Production (KS)	N_2O	10 718	1 085	-2	2	–	-90	-95	-95	-90	–
2.C. Metal Production	–	–	–	–	–	–	–	18	14	22	–
2.C.1. Iron and Steel Production (KS)	CO_2	7 058	7 041	-5	5	–	0	4	3	6	See Note 1
2.C.3. Aluminium Production (Total GHGs)	CO_2 (eq)	8 933.24	7 318.25	–	–	–	-18	20	-35	-19	See Note 1
(Breakdown of the GHG Emissions)	CO_2 (KS)	2 636.20	4 577.20	–	–	–	74	60	45	70	See Note 1
	CF_4	5 679.44	2 479.70	–	–	–	-56	4	-70	-60	See Note 2
	C_2F_6	617.60	261.35	–	–	–	-58	-8	-75	-60	See Note 2
	PFC (KS)	6 297.04	2 741.05	–	–	–	-56	3	-69	-59	See Note 2
2.C.4. SF_6 Used in Magnesium Foundries (KS)	SF_6	2 870.39	2 232.021	-1	1	–	-22	-30	-30	-29	–
2.G. Other	–	–	–	–	–	–	–	–	–	–	–
Other and Undifferentiated Production (KS)	CO_2	9 218	13 715	-40	1	–	49	27	-30	50	See Note 3
Total GHG Emissions from Industrial Processes	CO_2 (eq)	54 393	48 899	-7	5	–	-10	-9	-27	-12	–
Total CO_2 Emissions – Industrial Processes	CO_2	31 697	40 195	2	19	–	27	18	-3	27	See Note 4; differences are due to the change in CO_2 emission estimates (for 1990–2002) for aluminium production, which are subtracted from the total non-energy emissions to avoid double-counting
Total N_2O Emissions – Industrial Processes	N_2O	11 495	1 891	-8	8	–	-84	–	–	–	–
Total PFC Emissions – Industrial Processes	PFC	6 297	2 741	-70	-60	–	-56	–	–	–	See Note 4; differences are due to the change in CO_2 emission estimates (for 1990–2002) for aluminium production, which are subtracted from the total non-energy emissions to avoid double-counting
Total SF_6 Emissions – Industrial Processes	SF_6	4 903	4 072	-1	1	–	-17	–	–	–	See Note 4; differences are due to addition of new SF_6 sources: SF_6 from casters and electrical utilities
Total GHG Emissions from ODS Substitutes	CO_2			-20	55	–	–	–	–	–	–
Total HFC Emissions from ODS Substitutes (KS)	HFC	0	3 090	-21	55	–	–	–	–	–	See Note 5
Total PFC Emissions from ODS Substitutes (KS)	PFC	0	19	-28	70	–	–	–	–	–	–
New Sources											
2.C.5. Magnesium Casting (SF_6) (KS)	CO_2 (eq)	236.61	246.648	–	–	–	4	–	–	–	See Note 6; weighted average uncertainty estimates are provided in a recent study done by Cheminfo: for 1990, 8%, and for 2003, 4%
2.F.8. Electrical Equipment (SF_6) (KS)	CO_2 (eq)	1 796.4699	1 593.72	–	–	–	-11	–	–	–	See Note 6; weighted average uncertainty estimates are to be provided by Cheminfo
3. Solvent and Other Product Use	–	–	–	–	–	–	–	–	–	–	–
Total Emissions from Solvent Use (KS)	N_2O	417.29	476.53	-23	22	–	14	12	12	12	See Note 3; differences are due to the update in population statistics

Notes:

1 There has been a methodological improvement in this category since 2004 (i.e., 2002 inventory). The uncertainty estimates in the ICF report were associated with the emission estimates shown in the 2001 inventory. The current emission numbers developed using an improved methodology have not been assessed for their uncertainties. However, the uncertainty values provided in the ICF study can be considered as acceptable, since they are actually uncertainties for worst-case emission estimates. In other words, they are conservative estimates of uncertainty for improved and more accurate emission figures.

2 Audited data were obtained directly from the AAC. The uncertainty estimates in the ICF report were associated with the emission estimates developed using emission factors (as shown in the 2001 inventory). Therefore, they are not applicable to the current emission estimates, which are significantly more accurate than before. One of the planned improvements for this category is to obtain, from industry experts, uncertainty estimates that correspond to the current emission figures.

3 The 1990–2002 emission estimates for this category shown in the 2003 inventory are different from the ones in previous inventories. Differences are due to the change in CO_2 emission estimates (for 1990–2002) for aluminium production, which are subtracted from the total non-energy emissions to avoid double-counting. The current emission numbers have not been assessed for their uncertainties. However, the change in emissions should not affect the uncertainty estimates provided by ICF, since the data source and methodology used are the same for both 2001 and 2003 inventories.

4 The 1990–2002 emission estimates shown in the 2003 inventory are different from the ones in previous inventories. Differences come from the reasons mentioned above. The current emission numbers have not been assessed for their uncertainties. However, the uncertainty values provided in the ICF study can be considered as acceptable, since they are actually uncertainties for worst-case emission estimates. In other words, they are conservative estimates of uncertainty for improved and more accurate emission figures.

5 There has been a methodological improvement in calculating emissions from HFC consumption for the 2003 inventory. The uncertainty estimates in the ICF report were associated with the emission estimates shown in the 2001 inventory. The current emission numbers developed using an improved methodology have not been assessed for their uncertainties. However, the uncertainty values provided in the ICF study can be considered as acceptable, since they are actually uncertainties for worst-case emission estimates. In other words, they are conservative estimates of uncertainty for improved and more accurate emission figures.

6 The emission estimates of this category were not assessed for their uncertainties when ICF conducted the study, since this category is a new source considered in the 2003 inventory.

ODS = ozone-depleting substance; (KS) = Key Source

TABLE A7-15: Tier 2 Uncertainty Reporting — Agriculture

IPCC Source Category	Gas	Base Year Emissions (1990)	Year t Emissions (2003)	Uncertainty in Year t Emissions as % of Emissions in the Category		Uncertainty Introduced on National Total in Year t	% Change in Emissions between Year t and Base Year	% Change in Emissions between 2001 and 1990 as per ICF Study	Range of Likely % Change between 2001 and 1990 as per ICF Study		Commments
		Gg CO_2 eq	Gg CO_2 eq	% Below (2.5th percentile)	% Above (97.5th percentile)	%	%	%	Lower% (2.5th percentile)	Upper % (97.5th percentile)	Method changes or any other factors that would alter the estimated uncertainty from 2001
4.A. Entric Fermentation (KS)	CH_4	18 682.02	22 410.41	-9	9	–	20	18	15	20	ICF (2004)
4.A.1. Cattle	CH_4	18 044.40	21 402.39	-10	10	–	19	–	–	–	ICF (2004)
4.A.1.a. Dairy Cattle	CH_4	4 576.41	3 587.27	-17	17	–	-22	–	–	–	ICF (2004)
Dairy Cows	CH_4	3 625.42	2 805.29	-20	20	–	-23	–	–	–	See Note 1
Dairy Heifers	CH_4	951.00	781.98	-20	20	–	-18	–	–	–	See Note 1
4.A.1.b. Non-Dairy Cattle	CH_4	13 467.99	17 815.12	-11	11	–	32	–	–	–	See Note 1
Bulls	CH_4	439.12	506.53	-20	20	–	15	–	–	–	See Note 1
Beef Cows	CH_4	6 786.42	9 136.45	-20	20	–	35	–	–	–	See Note 1
Beef Heifers	CH_4	1 038.79	1 204.95	-20	20	–	16	–	–	–	See Note 1
Heifers for Slaughter	CH_4	747.16	1 261.15	-20	20	–	69	–	–	–	See Note 1
Steers	CH_4	1 302.42	1 644.34	-20	20	–	26	–	–	–	See Note 1
Calves	CH_4	3 154.07	4 061.69	-20	20	–	29	–	–	–	See Note 1
Non-Cattle Livestock	CH_4	637.62	1 008.02	-13	13	–	58	–	–	–	ICF (2004)
4.A.8. Boars, Sows and Pigs	CH_4	321.66	460.55	-20	20	–	43	–	–	–	ICF (2004)
4.A.3. Sheep and Lambs	CH_4	119.82	186.87	-20	20	–	56	–	–	–	ICF (2004)
4.A.4. Goats	CH_4	9.25	19.20	-20	20	–	108	–	–	–	ICF (2004)
4.A.6. Horses	CH_4	134.65	174.10	-20	20	–	29	–	–	–	ICF (2004)
4.A.7. Buffalo	CH_4	52.25	167.31	-20	20	–	220	–	–	–	Not estimated in ICF (2004), but this source of uncertainty is assumed to be about the same as for steers
4.B. Manure Management	CH_4 (KS)	3 128.15	3 662.54	-15	15	–	17	19	15	23	ICF (2004)
	N_2O (KS)	3 450.65	4 131.05	-30	35	–	20	25	-10	60	ICF (2004)
	CO_2 (eq)	6 578.80	7 793.59	-16	18	–	18	22	6	40	ICF (2004)
4.B.1. Cattle Livestock	CH_4	1 654.59	1 554.45	-21	21	–	-6	–	–	–	See Note 1
4.B.1.a. Dairy	CH_4	935.13	723.59	-25	25	–	-23	–	–	–	See Note 1
4.B.1.b. Non-Dairy Cattle	CH_4	719.47	830.86	-25	25	–	15	–	–	–	See Note 1
Non-Cattle Livestock	CH_4	1 473.56	2 108.09	-20	19	–	43	–	–	–	See Note 1
4.B.8. Boars, Sows and Pigs (Swine)	CH_4	1 358.96	1 958.19	-25	25	–	44	–	–	–	See Note 1
4.B.3. Sheep and Lambs	CH_4	4.44	6.97	-25	25	–	57	–	–	–	See Note 1
4.B.4. Goats	CH_4	0.41	0.84	–	–	–	108	–	–	–	Not estimated in ICF (2004)
4.B.6. Horses	CH_4	15.71	20.31	–	–	–	29	–	–	–	Not estimated in ICF (2004)
4.B.9. Chicken, Hens and Turkeys	CH_4	92.14	115.68	-25	25	–	26	–	–	–	See Note 1
4.B.10. Buffalo	CH_4	1.90	6.08	-25	25	–	220	–	–	–	Not estimated in ICF (2004), but this source of uncertainty is assumed to be about the same as for steers
Manure Management Systems											
4.B.11. Liquid Systems	N_2O	102.19	118.30	-35	35	–	16	–	–	–	Original uncertainty was assessed based on animal types (ICF, 2004), rather than manure management systems, but it is assumed similar
4.B.12. Solid Storage & Drylot	N_2O	3 302.46	3 951.82	-35	35	–	20	–	–	–	Original uncertainty was assessed based on animal types (ICF, 2004), rather than manure management systems, but it is assumed similar
4.B.13. Other	N_2O	46.00	60.93	-40	40	–	32	–	–	–	Original uncertainty was assessed based on animal types (ICF, 2004), rather than manure management systems, but it is assumed similar
4.D. Agricultural Soils											
Direct Soil Emissions (KS)	N_2O	21 758.12	25 364.85	-25	35	–	17	11	7	16	ICF (2004)
Synthetic Fertilizers	N_2O	6 556.27	8 816.77	-25	35	–	34	–	–	–	ICF (2004)
Manure as Fertilizer	N_2O	2 765.11	3 280.76	-30	35	–	19	–	–	–	ICF (2004)
Biological Nitrogen Fixation	N_2O	3 772.90	3 779.12	-35	50	–	0	–	–	–	ICF (2004)
Crop Residue Decomposition	N_2O	6 004.89	6 154.48	-40	55	–	2	–	–	–	ICF (2004)
Cultivated Organic Histosols	N_2O	61.01	61.01	-35	35	–	0	–	–	–	ICF (2004)
Grazing Animals	N_2O	2 597.93	3 272.71	-35	45	–	26	–	–	–	ICF (2004)
Indirect Soil Emissions (KS)	N_2O	5 105.05	6 549.98	-60	120	–	28	28	24	35	ICF (2004)
Volatilization and Subsequent Atmospheric Deposition of NH_3 & NO_x	N_2O	1 395.60	1 767.14	-75	130	–	27	–	–	–	ICF (2004)
Nitrogen Leaching and Runoff	N_2O	3 709.45	4 782.84	-75	160	–	29	–	–	–	ICF (2004)
Total (Direct and Indirect Soil Emissions)	N_2O	26 863.17	31 914.82	-25	40	–	19	15	11	20	ICF (2004)

Notes:

1 Original uncertainty was assessed based on data obtained using the Tier 1 "emission estimation methodology" (ICF, 2004). A Tier 2 estimation method was recently adopted, and the uncertainty estimates need to be reassessed.

(KS) = Key Source

TABLE A7-16: Tier 2 Uncertainty Reporting — Waste

IPCC Source Category	Gas	Base Year Emissions (1990)	Year t Emissions (2003)	Uncertainty in Year t Emissions as % of Emissions in the Category		Uncertainty introduced on National Total in Year t	% Change in Emissions between Year t and Base Year	% Change in Emissions between 2001 and 1990 as per ICF Study	Range of Likely % Change between 2001 and 1990 as per ICF Study		Comments
.		Gg CO_2 eq	Gg CO_2 eq	% Below (2.5th percentile)	% Above (97.5th percentile)	%	%	%	Lower % (2.5th percentile)	Upper % (97.5th percentile)	Method changes or any other factors that would alter the estimated uncertainty from 2001
6.A. Solid Waste Disposal on Land (KS)	CH_4	18 530.4691	23 701.553	-35	40	–	28	25	29	55	–
Emissions from MSW Landfills	CH_4	17 029.0836	21 558.741	-40	35	–	27	25	27	55	See Note 1
Emissions from Wood Waste	CH_4	1 501.38552	2 142.8117	-60	190	–	43	35	35	40	See Note 2
6.B. Wastewater Handling/Treatment (KS)	CO_2 (eq)	1 222.18738	1 395.7979	-40	55	–	14	12	12	13	–
Emissions from Wastewater Treatment	CH_4	355.419298	405.97699	-40	45	–	14	13	12	13	See Note 2
	N_2O	866.768087	989.82092	-60	65	–	14	12	12	12	The wastewater input uncertainties were assumed values.
6.C. Waste Incineration (KS)	CO_2 (eq)	316.978060	355.15240	-12	65	–	12	10	10	11	–
Emissions from MSW Incineration	CO_2	254.187316	287.72020	-3	85	–	13	12	11	12	Uncertainties for all inputs were assumed.
	N_2O	53.5898885	60.509164	-80	85	–	13	11	11	12	Uncertainties for all inputs were assumed, except for the N_2O emissions, which were based on IPCC estimates.
Emissions from Sewage Sludge Incineration	CH_4	9.200856	6.9230381	-60	60	–	-25	-25	-30	-19	The uncertainty range for the CH_4 emission factor for fluidized beds in the 2001 inventory year was assumed. For simplicity, the multihearth incinerators were not included. Uncertainty about the quantity of sewage sludge incinerated was assumed based upon IPCC values.

Notes:

1 The accuracy of these values is subject to the following limitations: (1) the uncertainty values from the ICF (2004) study were calculated from the Monte Carlo method employing a much simplified CH_4 generation model compared with that utilized in the NIR, (2) only one expert's opinion was used to provide the uncertainty lower and upper limits for each activity data input (CH_4 volume capture, MSW landfilling rate per capita, Scholl Canyon constants (CH_4 generation potential, L_0, and the CH_4 rate constant, k)), and population statistics. A revision of the landfill gas collection inventory in 2004 has since found the 2001 inventory value of the quantity of CH_4 captured to be 10% overestimated. The uncertainty about the quantity of CH_4 captured was overestimated due to a transcription error.

2 The input values for this category were IPCC default values or assumed values.

(KS) = Key Source

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ANNEX 8: CANADA'S GREENHOUSE GAS EMISSION TABLES, 1990–2003

Annex 8 contains summary tables illustrating national GHG emissions by year, gas, and sector.

TABLE A8-1: Greenhouse Gas Category Description

GHG Source/Sink Categories	
ENERGY	
a. Stationary Combustion Sources	
Electricity and Heat Generation	Emissions from fuel consumed by:
Electricity Generation	Utility and industry electricity generation
Heat Generation	Steam generation (for sale)
Fossil Fuel Industries	Emissions from fuel consumed by:
Petroleum Refining	Petroleum refining industries (including upstream facilities)
Fossil Fuel Production	Conventional and unconventional oil and gas production industries (some refining is included)
Mining	Emissions from commercial fuel sold to: Metal and non-metal mines, stone quarries, and gravel pits Oil and gas extraction industries Mineral exploration and contract drilling operation
Manufacturing Industries	Emissions from fuel consumed by the following industrie: Iron and steel (steel foundries, casting and rolling mills) Non-Ferrous metals (aluminium, magnesium, and other production) Chemical (fertilizer manufacturing, organic and inorganic chemical manufacturing) Pulp and paper (primarily pulp, paper and paper product manufacturers) Cement production Other manufacturing industries not listed (such as automobile manufacturing, textiles, food and beverage industries)
Construction	Emissions from fuels consumed by the construction industry – buildings, highways, etc.
Commercial & Institutional	Emissions from fuel consumed by: Service industries related to mining, communication, wholesale and retail trade, finance and insurance, real estate, education, etc. Federal, provincial, and municipal establishments National Defence and Canadian Coast Guard Train stations, airports, and warehouses
Residential	Emissions from fuels consumed for personal residences (homes, apartment hotels, condominiums, and farms)
Agriculture & Forestry	Emissions from fuel consumed by: Forestry and logging service industry Agriculture, hunting and trapping industry (excluding food processing, farm machinery manufacturing and repair)
b. Transportation	Emissions resulting from the combustion and/or fugitive releases due to moving passengers, freight, and commodities throughout Canada
Domestic Aviation	Emissions resulting from the consumption of fossil fuels by Canadian-registered airlines flying domestically
Road Transportation	Emissions resulting from the consumption of fossil fuels by vehicles licensed to operate on roads
Railways	Emissions resulting from the consumption of fossil fuels by Canadian railways
Domestic Marine	Emissions resulting from the consumption of fossil fuels by Canadian-registered marine vessels fuelled domestically
Others - Off-Road	Emissions resulting from the consumption of fossil fuels by combustion devices not licensed to operate on roads
Others - Pipelines	Emissions resulting from the transportation and distribution of crude oil, natural gas, and other products
c. Fugitive Sources	Intentional and unintentional releases of GHGs from the following activities:
Coal Mining	Underground and surface mining
Oil and Natural Gas	Conventional and unconventional oil and gas exploration, production, transportation, and distribution
INDUSTRIAL PROCESSES	Emissions resulting from the following process activities:
a. Mineral Production	Production of cement and lime; use of soda ash and limestone
b. Chemical Industry	Production of ammonia, nitric acid, and adipic acid
c. Metal Production	Production of aluminium, iron and steel; magnesium production and casting
d. Consumption of Halocarbons and SF_6	Use of HFCs and/or PFCs in air conditioning units, refrigeration units, fire extinguishers, aerosol cans, solvents, foam blowing, semi-conductor manufacturing and electronics industry; use of SF_6 in electrical equipment
e. Other & Undifferentiated Production	Non-energy use of fossil fuels
SOLVENT & OTHER PRODUCT USE	Emissions resulting from the use of N_2O as anaesthetic and propellant
AGRICULTURE	Emissions resulting from:
a. Enteric Fermentation	Livestock
b. Manure Management	Livestock waste management
c. Agricultural Soils	Direct and indirect emissions from mineral soils, histosols, atmospheric deposition, and runoff
Direct Sources	Emissions resulting from synthetic fertilizer, manure N on pasture and cropland, biological N fixation, crop residue, and cultivation of organic soils
Indirect Sources	Emissions from animal manure nitrogen and synthetic fertilizer nitrogen
WASTE	Emissions resulting from:
a. Solid Waste Disposal on Land	Municipal waste management sites (landfills) and wood waste landfills
b. Wastewater Handling	Domestic wastewater treatment
c. Waste Incineration	Waste incineration
LAND USE, LAND-USE CHANGE AND FORESTRY	Emissions and removals resulting from:
a. Forest Land	Managed forests including growth, harvests and fires, and from land conversion to forests
b. Cropland	Mineral and organic cropland soils management, liming, and land conversion to cropland (CO_2)
c. Grassland	Land conversion to grasslands
d. Wetlands	Peatlands management for peat extraction (under development)
e. Settlements	Urban trees and the conversion of vegetated land to urban lands

TABLE A8-2: 1990–2003 Canada's Greenhouse Gas Emissions by Sector

kt CO_2 eq

GHG Source/Sink Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
TOTAL	**596 000**	**589 000**	**606 000**	**608 000**	**630 000**	**646 000**	**663 000**	**675 000**	**682 000**	**696 000**	**720 000**	**712 000**	**719 000**	**740 000**
ENERGY	**469 000**	**461 000**	**478 000**	**478 000**	**494 000**	**508 000**	**522 000**	**534 000**	**543 000**	**558 000**	**582 000**	**576 000**	**583 000**	**600 000**
a. Stationary Combustion Sources	**282 000**	**277 000**	**287 000**	**281 000**	**287 000**	**295 000**	**302 000**	**307 000**	**313 000**	**323 000**	**345 000**	**340 000**	**346 000**	**358 000**
Electricity and Heat Generation	95 300	96 700	103 000	93 900	96 400	101 000	99 700	111 000	124 000	121 000	132 000	134 000	129 000	134 000
Fossil Fuel Industries	52 000	50 000	52 000	53 000	53 000	55 000	55 000	51 000	57 000	65 000	67 000	68 000	73 000	71 000
Petroleum Refining	26 000	26 000	27 000	28 000	27 000	28 000	29 000	27 000	27 000	27 000	28 000	30 000	34 000	34 000
Fossil Fuel Production	25 000	24 000	25 000	25 000	26 000	26 000	27 000	24 000	30 000	38 000	39 000	38 000	39 000	38 000
Mining	6 200	5 080	4 900	7 420	7 490	7 860	8 740	8 970	8 020	7 450	10 400	10 300	11 800	15 700
Manufacturing Industries	54 900	52 400	51 800	49 300	52 400	53 100	54 800	54 800	52 600	52 900	53 200	49 000	49 100	49 200
Iron and Steel	6 490	6 450	6 720	6 660	7 470	7 040	7 330	7 300	7 000	7 280	7 190	5 890	6 490	6 420
Non-Ferrous Metals	3 230	2 610	2 830	2 730	3 310	3 110	3 500	3 180	3 410	3 260	3 190	3 470	3 220	3 200
Chemical	7 100	7 480	7 450	7 310	8 530	8 460	8 800	8 890	8 570	8 460	7 860	6 760	6 130	5 740
Pulp and Paper	13 600	13 000	12 200	12 100	12 000	11 700	12 200	12 000	11 100	11 100	11 000	9 790	9 210	9 130
Cement	3 590	3 000	2 870	2 860	3 280	3 420	3 270	3 250	3 290	3 990	3 970	3 930	4 180	4 200
Other Manufacturing	20 900	19 900	19 600	17 600	17 800	19 400	19 700	20 100	19 200	18 800	20 000	19 100	19 900	20 500
Construction	1 880	1 630	1 750	1 390	1 400	1 180	1 270	1 260	1 120	1 170	1 080	1 010	1 240	1 300
Commercial & Institutional	25 800	26 500	27 000	28 100	27 400	29 000	29 600	30 000	27 200	28 900	33 200	33 200	35 400	39 000
Residential	44 000	42 000	43 000	46 000	46 000	45 000	5 000	46 000	41 000	43 000	45 000	42 000	44 000	45 000
Agriculture & Forestry	2 420	2 760	3 270	3 060	2 560	2 790	2 950	2 940	2 610	2 690	2 570	2 210	2 110	2 210
b. Transportation	**150 000**	**140 000**	**150 000**	**150 000**	**160 000**	**160 000**	**170 000**	**170 000**	**180 000**	**180 000**	**180 000**	**180 000**	**180 000**	**190 000**
Domestic Aviation	6 400	5 700	5 500	5 300	5 500	5 900	6 200	6 400	6 500	6 600	6 600	6 200	6 800	7 200
Road Transportation	107 000	104 000	108 000	110 000	116 000	119 000	12 000	126 000	127 000	131 000	131 000	133 000	137 000	140 000
Light-Duty Gasoline Vehicles	53 800	51 300	51 600	51 800	52 300	51 400	49 900	50 100	49 700	49 700	48 200	49 100	49 700	49 300
Light-Duty Gasoline Trucks	21 700	22 200	24 000	25 500	27 400	28 400	29 900	31 900	32 700	36 700	37 600	38 800	40 700	41 900
Heavy-Duty Gasoline Vehicles	3 140	3 340	3 740	4 080	4 490	4 760	4 990	5 050	5 500	4 210	4 370	4 040	4 140	4 140
Motorcycles	230	221	218	220	222	214	210	220	232	233	238	239	227	226
Light-Duty Diesel Vehicles	672	635	633	626	618	594	603	600	597	605	604	642	683	723
Light-Duty Diesel Trucks	591	507	456	429	432	417	402	505	455	500	645	681	755	793
Heavy-Duty Diesel Vehicles	24 500	23 800	24 300	25 700	28 500	30 800	32 500	35 500	35 600	37 300	38 700	38 500	39 600	42 000
Propane & Natural Gas Vehicles	2 200	2 300	2 700	2 000	1 900	2 100	2 000	1 800	1 800	1 500	1 100	1 100	850	810
Railways	7 000	7 000	7 000	7 000	7 000	6 000	6 000	6 000	6 000	7 000	7 000	7 000	6 000	6 000
Domestic Marine	5 000	5 200	5 100	4 500	4 700	4 400	4 500	4 500	5 100	5 000	5 100	5 500	5 500	6 100
Others	20 000	20 000	20 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000
Off-Road Gasoline	5 000	5 000	4 000	4 000	4 000	4 000	5 000	4 000	6 000	5 000	6 000	5 000	4 000	4 000
Off-Road Diesel	10 000	10 000	9 000	10 000	10 000	10 000	10 000	10 000	10 000	20 000	20 000	10 000	10 000	20 000
Pipelines	6 900	7 650	9 890	10 400	10 800	12 000	12 500	12 600	12 500	12 600	11 300	10 300	10 900	9 110
c. Fugitive Sources	**37 900**	**39 600**	**42 400**	**44 400**	**46 600**	**49 800**	**52 700**	**52 800**	**52 400**	**52 800**	**54 000**	**54 900**	**54 500**	**54 000**
Coal Mining	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	1 000	1 000	900	1 000	1 000	1 000
Oil and Natural Gas	36 000	37 500	40 600	42 500	44 900	48 100	51 000	51 200	51 000	51 700	53 000	53 900	53 500	53 000
Oil	8 600	9 200	10 000	11 000	11 000	13 000	14 000	14 000	14 000	13 000	14 000	14 000	13 000	13 000
Natural Gas	17 000	18 000	19 000	20 000	21 000	22 000	23 000	23 000	23 000	23 000	24 000	24 000	24 000	24 000
Venting	4 500	4 800	5 300	5 800	6 200	6 700	6 900	6 900	7 200	7 400	7 500	7 800	8 100	7 800
Flaring	5 800	5 700	5 800	6 000	6 100	6 800	7 200	7 300	7 200	7 600	7 800	8 000	8 000	8 000
INDUSTRIAL PROCESSES	**54 400**	**55 200**	**53 600**	**54 400**	**56 600**	**57 300**	**58 400**	**57 900**	**55 300**	**52 700**	**52 400**	**50 800**	**51 000**	**52 000**
a. Mineral Production	**7 800**	**7 000**	**7 000**	**7 100**	**7 700**	**8 100**	**8 100**	**8 400**	**9 900**	**9 300**	**9 000**	**8 500**	**8 600**	**8 700**
Cement	5 600	4 800	4 700	5 000	5 600	5 900	6 000	6 200	6 400	6 600	6 700	6 500	6 700	6 800
Lime	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Limestone and Soda Ash Use	440	430	460	310	290	360	340	370	1 700	750	420	350	230	230
b. Chemical Industry	**17 000**	**16 000**	**16 000**	**16 000**	**18 000**	**18 000**	**19 000**	**17 000**	**12 000**	**9 400**	**8 500**	**7 500**	**8 300**	**8 100**
Ammonia Production	5 000	4 900	5 100	5 700	5 800	6 500	6 500	6 700	6 600	6 800	6 800	5 900	6 200	6 200
Nitric Acid Production	780	770	780	780	770	780	790	790	770	790	800	800	810	810
Adipic Acid Production	10 700	10 000	9 950	9 080	11 000	10 700	11 500	9 890	5 070	1 750	900	802	1 250	1 090
c. Metal Production	**19 100**	**21 000**	**20 100**	**20 100**	**19 000**	**19 100**	**18 200**	**17 900**	**18 100**	**18 300**	**18 400**	**16 900**	**17 100**	**16 800**
Iron and Steel Production	7 060	8 320	8 500	8 180	7 540	7 880	7 740	7 550	7 690	7 890	7 890	7 280	7 110	7 040
Aluminium Production	8 930	9 110	9 150	9 700	9 170	9 090	8 810	8 720	8 550	8 210	7 730	7 360	7 110	7 320
SF_6 Used in Magnesium Smelters and Casters	3 110	3 590	2 400	2 210	2 280	2 110	1 600	1 620	1 900	2 180	2 790	2 300	2 910	2 480
d. Consumption of Halocarbons and SF_6	**1 800**	**1 900**	**1 700**	**2 000**	**1 800**	**2 000**	**2 000**	**2 800**	**3 300**	**3 900**	**4 600**	**5 100**	**4 200**	**4 700**
e. Other & Undifferentiated Production	**9 200**	**9 600**	**9 000**	**9 700**	**11 000**	**10 000**	**11 000**	**11 000**	**11 000**	**12 000**	**12 000**	**13 000**	**13 000**	**14 000**
SOLVENT & OTHER PRODUCT USE	**420**	**420**	**430**	**430**	**440**	**440**	**450**	**450**	**450**	**460**	**460**	**470**	**470**	**480**
AGRICULTURE	**52 000**	**52 000**	**53 000**	**54 000**	**57 000**	**58 000**	**60 000**	**60 000**	**60 000**	**61 000**	**61 000**	**60 000**	**59 000**	**62 000**
a. Enteric Fermentation	**18 700**	**18 900**	**19 400**	**19 600**	**20 600**	**21 300**	**21 300**	**21 500**	**21 100**	**20 900**	**20 800**	**22 200**	**22 200**	**22 400**
b. Manure Management	**6 600**	**6 600**	**6 700**	**6 700**	**7 000**	**7 200**	**7 300**	**7 300**	**7 300**	**7 200**	**7 200**	**7 700**	**7 800**	**7 800**
c. Agricultural Soils	**27 000**	**26 000**	**27 000**	**28 000**	**29 000**	**30 000**	**31 000**	**31 000**	**32 000**	**33 000**	**33 000**	**31 000**	**29 000**	**32 000**
Direct Sources	22 000	21 000	21 000	22 000	23 000	24 000	25 000	25 000	25 000	26 000	26 000	24 000	23 000	25 000
Indirect Sources	5 000	5 000	5 000	5 000	6 000	6 000	6 000	7 000	6 000	6 000	7 000	6 000	6 000	7 000
WASTE	**20 000**	**21 000**	**21 000**	**22 000**	**22 000**	**22 000**	**22 000**	**23 000**	**24 000**	**24 000**	**25 000**	**24 000**	**25 000**	**25 000**
a. Solid Waste Disposal on Land	**19 000**	**19 000**	**20 000**	**20 000**	**20 000**	**20 000**	**20 000**	**21 000**	**22 000**	**22 000**	**23 000**	**23 000**	**23 000**	**24 000**
b. Wastewater Handling	**1 200**	**1 200**	**1 300**	**1 300**	**1 300**	**1 300**	**1 300**	**1 300**	**1 300**	**1 300**	**1 400**	**1 400**	**1 400**	**1 400**
c. Waste Incineration	**320**	**320**	**330**	**330**	**330**	**330**	**340**	**340**	**340**	**340**	**350**	**350**	**350**	**360**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-150 000**	**-130 000**	**-140 000**	**-110 000**	**-110 000**	**7 600**	**-89 000**	**-100 000**	**-60 000**	**-68 000**	**-85 000**	**-89 000**	**-33 000**	**-44 000**
a. Forest Land	**-190 000**	**-170 000**	**-170 000**	**-140 000**	**-140 000**	**-22 000**	**-120 000**	**-130 000**	**-86 000**	**-94 000**	**-110 000**	**-110 000**	**-58 000**	**-69 000**
b. Cropland[2]	**23 000**	**23 000**	**22 000**	**21 000**	**20 000**	**19 000**	**18 000**	**17 000**	**17 000**	**16 000**	**16 000**	**15 000**	**15 000**	**14 000**
c. Grassland	**5 000**	**5 000**	**5 000**	**5 000**	**5 000**	**5 000**	**5 000**	**5 000**	**5 000**	**5 000**	**5 000**	**5 000**	**5 000**	**5 000**
d. Wetlands	–	–	–	–	–	–	–	–	–	–	–	–	–	–
e. Settlements	**6 000**	**6 000**	**6 000**	**6 000**	**6 000**	**6 000**	**6 000**	**6 000**	**6 000**	**6 000**	**6 000**	**6 000**	**6 000**	**6 000**

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-3: 2003 Greenhouse Gas Emissions Summary for Canada

	Greenhouse Gases								
GHG Source/Sink Categories	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			21		310				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**586 000**	**4 500**	**94 000**	**160**	**50 000**	**3 100**	**2 760**	**4 100**	**740 000**
ENERGY	**546 000**	**2 000**	**40 000**	**30**	**10 000**	–	–	–	**600 000**
a. **Stationary Combustion Sources**	**351 000**	**200**	**5 000**	**9**	**3 000**	–	–	–	**358 000**
Electricity and Heat Generation	133 000	5.0	110	2	800	–	–	–	134 000
Fossil Fuel Industries	69 000	100	2 000	2	500	–	–	–	71 000
Petroleum Refining	34 000	0.5	10	0.5	100	–	–	–	34 000
Fossil Fuel Production	34 800	100	2 000	1	300	–	–	–	38 000
Mining	15 600	0.3	7	0.3	100	–	–	–	15 700
Manufacturing Industries	48 600	3	60	2	500	–	–	–	49 200
Iron and Steel	6 360	0.2	5	0.2	60	–	–	–	6 420
Non-Ferrous Metals	3 190	0.07	1	0.05	20	–	–	–	3 200
Chemical	5 700	0.12	2.5	0.1	30	–	–	–	5 740
Pulp and Paper	8 820	2	40	0.9	300	–	–	–	9 130
Cement	4 180	0.08	2	0.05	10	–	–	–	4 200
Other Manufacturing	20 400	0.4	9	0.4	100	–	–	–	20 500
Construction	1 290	0.02	0.5	0.03	9	–	–	–	1 300
Commercial & Institutional	38 800	0.7	10	0.8	200	–	–	–	39 000
Residential	42 800	90	2 000	2	500	–	–	–	45 000
Agriculture & Forestry	2 200	0.04	0.8	0.06	20	–	–	–	2 210
b. **Transportation**	**179 000**	**30**	**600**	**30**	**8 000**	–	–	–	**190 000**
Domestic Aviation	7 000	0.4	9	0.7	200	–	–	–	7 200
Road Transportation	135 000	12	260	17	5 100	–	–	–	140 000
Light-Duty Gasoline Vehicles	47 300	3.7	78	6.3	1 900	–	–	–	49 300
Light-Duty Gasoline Trucks	39 200	4.5	94	8.4	2 600	–	–	–	41 900
Heavy-Duty Gasoline Vehicles	3 950	0.55	12.0	0.59	180	–	–	–	4 140
Motorcycles	221	0.18	3.7	0.00	1.3	–	–	–	226
Light-Duty Diesel Vehicles	706	0.02	0.4	0.05	20	–	–	–	723
Light-Duty Diesel Trucks	775	0.02	0.4	0.06	20	–	–	–	793
Heavy-Duty Diesel Vehicles	41 600	2	40	1	400	–	–	–	42 000
Propane & Natural Gas Vehicles	780	1	30	0.02	5	–	–	–	810
Railways	5 260	0.3	6	2	700	–	–	–	6 000
Domestic Marine	5 830	0.5	10	1	300	–	–	–	6 100
Others	26 000	10	300	6	2 000	–	–	–	30 000
Off-Road Gasoline	4 000	5	100	0.09	30	–	–	–	4 000
Off-Road Diesel	13 000	0.7	10	5	2 000	–	–	–	20 000
Pipelines	8 850	8.8	190	0.2	70	–	–	–	9 110
c. **Fugitive Sources**	**15 000**	**1 800**	**39 000**	–	–	–	–	–	**54 000**
Coal Mining	–	50	1 000	–	–	–	–	–	1 000
Oil and Natural Gas	15 000	1 800	38 000	–	–	–	–	–	53 000
Oil	47.1	630	13 000	–	–	–	–	–	13 000
Natural Gas	29	1 100	24 000	–	–	–	–	–	24 000
Venting	7 800	–	–	–	–	–	–	–	7 800
Flaring	7 380	31.2	654	–	–	–	–	–	8 000
INDUSTRIAL PROCESSES	**40 200**	–	–	**6.1**	**1 890**	**3 100**	**2 760**	**4 070**	**52 000**
a. **Mineral Production**	**8 700**	–	–	–	–	–	–	–	**8 700**
Cement	6 800	–	–	–	–	–	–	–	6 800
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	230	–	–	–	–	–	–	–	230
b. **Chemical Industry**	**6 200**	–	–	**6.1**	**1 890**	–	–	–	**8 100**
Ammonia Production	6 200	–	–	–	–	–	–	–	6 200
Nitric Acid Production	–	–	–	2.6	810	–	–	–	810
Adipic Acid Production	–	–	–	3.5	1 090	–	–	–	1 090
c. **Metal Production**	**12 000**	–	–	–	–	–	**2 740**	**2 480**	**16 800**
Iron and Steel Production	7 040	–	–	–	–	–	–	–	7 040
Aluminium Production	4 600	–	–	–	–	–	2 740	–	7 320
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	2 480	2 480
d. **Consumption of Halocarbons and SF_6**	–	–	–	–	–	**3 100**	**19**	**1 600**	**4 700**
e. **Other & Undifferentiated Production**	**14 000**	–	–	–	–	–	–	–	**14 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	**1.5**	**480**	–	–	–	**480**
AGRICULTURE	–	**1 240**	**26 100**	**120**	**36 000**	–	–	–	**62 000**
a. **Enteric Fermentation**	–	**1 070**	**22 400**	–	–	–	–	–	**22 400**
b. **Manure Management**	–	**170**	**3 700**	**13**	**4 100**	–	–	–	**7 800**
c. **Agricultural Soils**	–	–	–	**100**	**32 000**	–	–	–	**32 000**
Direct Sources	–	–	–	82	25 000	–	–	–	25 000
Indirect Sources	–	–	–	20	7 000	–	–	–	7 000
WASTE	**290**	**1 100**	**24 000**	**3**	**1 000**	–	–	–	**25 000**
a. **Solid Waste Disposal on Land**	–	**1 100**	**24 000**	–	–	–	–	–	**24 000**
b. **Wastewater Handling**	–	**19**	**410**	**3**	**1 000**	–	–	–	**1 400**
c. **Waste Incineration**	**290**	**0.3**	**7**	**0.2**	**60**	–	–	–	**360**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-46 000**	**43**	**900**	**3.2**	**1 000**	–	–	–	**-44 000**
a. **Forest Land**	**-71 000**	**43**	**900**	**3.2**	**1 000**	–	–	–	**-69 000**
b. **Cropland**[2]	**14 000**	–	–	–	–	–	–	–	**14 000**
c. **Grassland**	**5 000**	–	–	–	–	–	–	–	**5 000**
d. **Wetlands**	–	–	–	–	–	–	–	–	-
e. **Settlements**	**6 000**	–	–	–	–	–	–	–	**6 000**

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-4: 2002 Greenhouse Gas Emissions Summary for Canada

GHG Source/Sink Categories	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
	Greenhouse Gases								
Global Warming Potential			21		310				
Unit	kt	kt	kt CO_2 eq	kt	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq
TOTAL	**568 000**	**4 500**	**94 000**	**150**	**48 000**	**3 100**	**2 710**	**4 000**	**719 000**
ENERGY	**528 000**	**2 000**	**40 000**	**30**	**10 000**	–	–	–	**583 000**
a. Stationary Combustion Sources	**338 000**	**200**	**5 000**	**8**	**3 000**	–	–	–	**346 000**
Electricity and Heat Generation	128 000	4.7	99	2	700	–	–	–	129 000
Fossil Fuel Industries	70 000	100	2 000	2	500	–	–	–	73 000
Petroleum Refining	34 000	0.5	10	0.5	100	–	–	–	34 000
Fossil Fuel Production	36 200	100	2 000	1	300	–	–	–	39 000
Mining	11 700	0.2	5	0.3	90	–	–	–	11 800
Manufacturing Industries	48 600	3	60	2	500	–	–	–	49 100
Iron and Steel	6 420	0.2	5	0.2	60	–	–	–	6 490
Non-Ferrous Metals	3 210	0.07	1	0.05	20	–	–	–	3 220
Chemical	6 090	0.12	2.6	0.1	30	–	–	–	6 130
Pulp and Paper	8 900	2	40	0.9	300	–	–	–	9 210
Cement	4 170	0.08	2	0.05	20	–	–	–	4 180
Other Manufacturing	19 800	0.4	8	0.4	100	–	–	–	19 900
Construction	1 230	0.02	0.5	0.03	9	–	–	–	1 240
Commercial & Institutional	35 200	0.6	10	0.7	200	–	–	–	35 400
Residential	41 000	90	2 000	2	500	–	–	–	44 000
Agriculture & Forestry	2 090	0.03	0.7	0.06	20	–	–	–	2 110
b. Transportation	**174 000**	**30**	**600**	**30**	**8 000**	–	–	–	**180 000**
Domestic Aviation	6 580	0.4	9	0.6	200	–	–	–	6 800
Road Transportation	131 000	12	260	17	5 300	–	–	–	137 000
Light-Duty Gasoline Vehicles	47 600	4.0	84	6.7	2 100	–	–	–	49 700
Light-Duty Gasoline Trucks	37 900	4.5	95	8.6	2 700	–	–	–	40 700
Heavy-Duty Gasoline Vehicles	3 950	0.55	12	0.59	180	–	–	–	4 140
Motorcycles	222	0.18	3.7	0.00	1.3	–	–	–	227
Light-Duty Diesel Vehicles	667	0.02	0.4	0.05	20	–	–	–	683
Light-Duty Diesel Trucks	738	0.02	0.4	0.05	20	–	–	–	755
Heavy-Duty Diesel Vehicles	39 200	2	40	1	400	–	–	–	39 600
Propane & Natural Gas Vehicles	819	1	30	0.02	5	–	–	–	850
Railways	5 280	0.3	6	2	700	–	–	–	6 000
Domestic Marine	5 150	0.4	8	1	300	–	–	–	5 500
Others	26 000	20	300	5	2 000	–	–	–	30 000
Off-Road Gasoline	4 000	4	90	0.08	20	–	–	–	4 000
Off-Road Diesel	12 000	0.6	10	5	2 000	–	–	–	10 000
Pipelines	10 600	11	220	0.3	90	–	–	–	10 900
c. Fugitive Sources	**16 000**	**1 900**	**39 000**	–	–	–	–	–	**54 500**
Coal Mining	–	50	1 000	–	–	–	–	–	1 000
Oil and Natural Gas	16 000	1 800	38 000	–	–	–	–	–	53 500
Oil	37.4	640	13 000	–	–	–	–	–	13 000
Natural Gas	29	1 100	24 000	–	–	–	–	–	24 000
Venting	8 100	–	–	–	–	–	–	–	8 100
Flaring	7 380	31.1	654	–	–	–	–	–	8 000
INDUSTRIAL PROCESSES	**39 200**	–	–	**6.65**	**2 060**	**3 100**	**2 710**	**3 960**	**51 000**
a. Mineral Production	**8 600**	–	–	–	–	–	–	–	**8 600**
Cement	6 700	–	–	–	–	–	–	–	6 700
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	230	–	–	–	–	–	–	–	230
b. Chemical Industry	**6 200**	–	–	**6.65**	**2 060**	–	–	–	**8 300**
Ammonia Production	6 200	–	–	–	–	–	–	–	6 200
Nitric Acid Production	–	–	–	2.6	810	–	–	–	810
Adipic Acid Production	–	–	–	4.03	1 250	–	–	–	1 250
c. Metal Production	**12 000**	–	–	–	–	–	**2 690**	**2 910**	**17 100**
Iron and Steel Production	7 110	–	–	–	–	–	–	–	7 110
Aluminium Production	4 400	–	–	–	–	–	2 690	–	7 110
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	2 910	2 910
d. Consumption of Halocarbons and SF_6	–	–	–	–	–	**3 100**	**19**	**1 000**	**4 200**
e. Other & Undifferentiated Production	**13 000**	–	–	–	–	–	–	–	**13 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	**1.5**	**470**	–	–	–	**470**
AGRICULTURE	–	**1 230**	**25 900**	**110**	**33 000**	–	–	–	**59 000**
a. Enteric Fermentation	–	**1 060**	**22 200**	–	–	–	–	–	**22 200**
b. Manure Management	–	**170**	**3 700**	**13**	**4 100**	–	–	–	**7 800**
c. Agricultural Soils	–	–	–	**95**	**29 000**	–	–	–	**29 000**
Direct Sources	–	–	–	74	23 000	–	–	–	23 000
Indirect Sources	–	–	–	20	6 000	–	–	–	6 000
WASTE	**290**	**1 100**	**24 000**	**3**	**1 000**	–	–	–	**25 000**
a. Solid Waste Disposal on Land	–	**1 100**	**23 000**	–	–	–	–	–	**23 000**
b. Wastewater Handling	–	**19**	**400**	**3**	**1 000**	–	–	–	**1 400**
c. Waste Incineration	**290**	**0.3**	**7**	**0.2**	**60**	–	–	–	**350**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-37 000**	**91**	**1 900**	**7.1**	**2 200**	–	–	–	**-33 000**
a. Forest Land	**-62 000**	**91**	**1 900**	**7.1**	**2 200**	–	–	–	**-58 000**
b. Cropland[2]	**15 000**	–	–	–	–	–	–	–	**15 000**
c. Grassland	**5 000**	–	–	–	–	–	–	–	**5 000**
d. Wetlands	–	–	–	–	–	–	–	–	–
e. Settlements	**6 000**	–	–	–	–	–	–	–	**6 000**

1 National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

2 CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-5: 2001 Greenhouse Gas Emissions Summary for Canada

	Greenhouse Gases								
GHG Source/Sink Categories	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	559 000	4 500	94 000	160	49 000	3 100	3 180	4 300	712 000
ENERGY	520 000	2 000	40 000	40	10 000	–	–	–	576 000
a. Stationary Combustion Sources	**333 000**	**200**	**5 000**	**8**	**3 000**	–	–	–	**340 000**
Electricity and Heat Generation	133 000	5.0	110	3	800	–	–	–	134 000
Fossil Fuel Industries	65 000	100	2 000	1	500	–	–	–	68 000
Petroleum Refining	30 000	0.5	10	0.4	100	–	–	–	30 000
Fossil Fuel Production	35 500	100	2 000	1	300	–	–	–	38 000
Mining	10 200	0.2	4	0.3	80	–	–	–	10 300
Manufacturing Industries	48 400	3	60	2	500	–	–	–	49 000
Iron and Steel	5 830	0.2	5	0.2	50	–	–	–	5 890
Non-Ferrous Metals	3 450	0.08	2	0.05	20	–	–	–	3 470
Chemical	6 720	0.14	2.9	0.1	40	–	–	–	6 760
Pulp and Paper	9 490	2	40	0.8	300	–	–	–	9 790
Cement	3 920	0.07	2	0.05	10	–	–	–	3 930
Other Manufacturing	19 000	0.4	8	0.4	100	–	–	–	19 100
Construction	1 000	0.02	0.4	0.02	8	–	–	–	1 010
Commercial & Institutional	33 000	0.6	10	0.7	200	–	–	–	33 200
Residential	39 400	90	2 000	2	500	–	–	–	42 000
Agriculture & Forestry	2 190	0.04	0.8	0.06	20	–	–	–	2 210
b. Transportation	**172 000**	**30**	**600**	**30**	**8 000**	–	–	–	**180 000**
Domestic Aviation	6 000	0.4	9	0.6	200	–	–	–	6 200
Road Transportation	127 000	13	270	17	5 400	–	–	–	133 000
Light-Duty Gasoline Vehicles	46 800	4.3	89	6.9	2 200	–	–	–	49 100
Light-Duty Gasoline Trucks	36 000	4.5	94	8.7	2 700	–	–	–	38 800
Heavy-Duty Gasoline Vehicles	3 850	0.54	11	0.57	180	–	–	–	4 040
Motorcycles	234	0.19	3.9	0.00	1.4	–	–	–	239
Light Duty Diesel Vehicles	628	0.02	0.4	0.05	10	–	–	–	642
Light-Duty Diesel Trucks	665	0.02	0.4	0.05	20	–	–	–	681
Heavy-Duty Diesel Vehicles	38 100	2	40	1	300	–	–	–	38 500
Propane & Natural Gas Vehicles	1 110	1	30	0.02	7	–	–	–	1 100
Railways	5 820	0.3	7	2	700	–	–	–	7 000
Domestic Marine	5 180	0.4	8	1	300	–	–	–	5 500
Others	28 000	20	300	6	2 000	–	–	–	30 000
Off-Road Gasoline	5 000	5	100	0.1	30	–	–	–	5 000
Off-Road Diesel	13 000	0.7	10	5	2 000	–	–	–	10 000
Pipelines	9 970	10	210	0.3	80	–	–	–	10 300
c. Fugitive Sources	**15 000**	**1 900**	**40 000**	–	–	–	–	–	**54 900**
Coal Mining	–	50	1 000	–	–	–	–	–	1 000
Oil and Natural Gas	15 000	1 800	39 000	–	–	–	–	–	53 900
Oil	38.9	660	14 000	–	–	–	–	–	14 000
Natural Gas	29	1 100	24 000	–	–	–	–	–	24 000
Venting	7 800	–	–	–	–	–	–	–	7 800
Flaring	7 380	31.3	657	–	–	–	–	–	8 000
INDUSTRIAL PROCESSES	38 600	–	–	5.15	1 600	3 100	3 180	4 320	50 800
a. Mineral Production	**8 500**	–	–	–	–	–	–	–	**8 500**
Cement	6 500	–	–	–	–	–	–	–	6 500
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	350	–	–	–	–	–	–	–	350
b. Chemical Industry	**5 900**	–	–	**5.15**	**1 600**	–	–	–	**7 500**
Ammonia Production	5 900	–	–	–	–	–	–	–	5 900
Nitric Acid Production	–	–	–	2.6	800	–	–	–	800
Adipic Acid Production	–	–	–	2.59	802	–	–	–	802
c. Metal Production	**11 000**	–	–	–	–	–	**3 160**	**2 300**	**16 900**
Iron and Steel Production	7 280	–	–	–	–	–	–	–	7 280
Aluminium Production	4 200	–	–	–	–	–	3 160	–	7 360
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	2 300	2 300
d. Consumption of Halocarbons and SF_6	–	–	–	–	–	**3 100**	**19**	**2 000**	**5 100**
e. Other & Undifferentiated Production	**13 000**	–	–	–	–	–	–	–	**13 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	1.5	470	–	–	–	470
AGRICULTURE	–	1 230	25 800	110	35 000	–	–	–	60 000
a. Enteric Fermentation	–	**1 060**	**22 200**	–	–	–	–	–	**22 200**
b. Manure Management	–	**170**	**3 600**	**13**	**4 100**	–	–	–	**7 700**
c. Agricultural Soils	–	–	–	**99**	**31 000**	–	–	–	**31 000**
Direct Sources	–	–	–	78	24 000	–	–	–	24 000
Indirect Sources	–	–	–	20	6 000	–	–	–	6 000
WASTE	280	1 100	23 000	3	1 000	–	–	–	24 000
a. Solid Waste Disposal on Land	–	**1 100**	**23 000**	–	–	–	–	–	**23 000**
b. Wastewater Handling	–	**19**	**400**	**3**	**1 000**	–	–	–	**1 400**
c. Waste Incineration	**280**	**0.3**	**7**	**0.2**	**60**	–	–	–	**350**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	-90 000	20	430	1.40	440	–	–	–	-89 000
a. Forest Land	**-120 000**	**20**	**430**	**1.40**	**440**	–	–	–	**-110 000**
b. Cropland[2]	**15 000**	–	–	–	–	–	–	–	**15 000**
c. Grassland	**5 000**	–	–	–	–	–	–	–	**5 000**
d. Wetlands	–	–	–	–	–	–	–	–	-
e. Settlements	**6 000**	–	–	–	–	–	–	–	**6 000**

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-6: 2000 Greenhouse Gas Emissions Summary for Canada

	Greenhouse Gases								
GHG Source/Sink Categories	**CO_2**	**CH_4**	**CH_4**	**N_2O**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**TOTAL**
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**566 000**	**4 400**	**92 000**	**170**	**51 000**	**3 100**	**3 850**	**4 300**	**720 000**
ENERGY	**526 000**	**2 000**	**40 000**	**40**	**10 000**	–	–	–	**582 000**
a. Stationary Combustion Sources	**337 000**	**200**	**5 000**	**8**	**3 000**	–	–	–	**345 000**
Electricity and Heat Generation	131 000	4.8	100	2	800	–	–	–	132 000
Fossil Fuel Industries	64 000	100	2 000	1	500	–	–	–	67 000
Petroleum Refining	28 000	0.5	10	0.4	100	–	–	–	28 000
Fossil Fuel Production	36 300	100	2 000	1	300	–	–	–	39 000
Mining	10 300	0.2	4	0.2	80	–	–	–	10 400
Manufacturing Industries	52 600	3	60	2	500	–	–	–	53 200
Iron and Steel	7 120	0.3	5	0.2	60	–	–	–	7 190
Non-Ferrous Metals	3 180	0.07	1	0.05	10	–	–	–	3 190
Chemical	7 820	0.16	3.3	0.1	40	–	–	–	7 860
Pulp and Paper	10 700	2	40	0.9	300	–	–	–	11 000
Cement	3 950	0.07	1	0.05	10	–	–	–	3 970
Other Manufacturing	19 800	0.4	8	0.4	100	–	–	–	20 000
Construction	1 070	0.02	0.4	0.03	8	–	–	–	1 080
Commercial & Institutional	33 000	0.6	10	0.7	200	–	–	–	33 200
Residential	42 500	90	2 000	2	500	–	–	–	45 000
Agriculture & Forestry	2 550	0.04	0.9	0.06	20	–	–	–	2 570
b. Transportation	**174 000**	**30**	**700**	**30**	**9 000**	–	–	–	**180 000**
Domestic Aviation	6 390	0.4	9	0.6	200	–	–	–	6 600
Road Transportation	126 000	13	280	18	5 600	–	–	–	131 000
Light-Duty Gasoline Vehicles	45 900	4.5	95	7.2	2 200	–	–	–	48 200
Light-Duty Gasoline Trucks	34 700	4.6	96	9.0	2 800	–	–	–	37 600
Heavy-Duty Gasoline Vehicles	4 170	0.58	12	0.62	190	–	–	–	4 370
Motorcycles	233	0.19	3.9	0.00	1.4	–	–	–	238
Light-Duty Diesel Vehicles	591	0.02	0.3	0.04	10	–	–	–	604
Light-Duty Diesel Trucks	630	0.02	0.4	0.05	10	–	–	–	645
Heavy-Duty Diesel Vehicles	38 300	2	40	1	300	–	–	–	38 700
Propane & Natural Gas Vehicles	1 060	2	40	0.02	7	–	–	–	1 100
Railways	5 920	0.3	7	2	700	–	–	–	7 000
Domestic Marine	4 780	0.3	7	1	300	–	–	–	5 100
Others	31 000	20	400	6	2 000	–	–	–	30 000
Off-Road Gasoline	5 000	6	100	0.1	40	–	–	–	6 000
Off-Road Diesel	15 000	0.8	20	6	2 000	–	–	–	20 000
Pipelines	11 000	11	230	0.3	90	–	–	–	11 300
c. Fugitive Sources	**15 000**	**1 900**	**39 000**	–	–	–	–	–	**54 000**
Coal Mining	–	50	900	–	–	–	–	–	900
Oil and Natural Gas	15 000	1 800	38 000	–	–	–	–	–	53 000
Oil	37.8	660	14 000	–	–	–	–	–	14 000
Natural Gas	28	1 100	24 000	–	–	–	–	–	24 000
Venting	7 500	–	–	–	–	–	–	–	7 500
Flaring	7 180	30.7	646	–	–	–	–	–	7 800
INDUSTRIAL PROCESSES	**39 400**	–	–	**5.48**	**1 700**	**3 100**	**3 850**	**4 290**	**52 400**
a. Mineral Production	**9 000**	–	–	–	–	–	–	–	**9 000**
Cement	6 700	–	–	–	–	–	–	–	6 700
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	420	–	–	–	–	–	–	–	420
b. Chemical Industry	**6 800**	–	–	**5.48**	**1 700**	–	–	–	**8 500**
Ammonia Production	6 800	–	–	–	–	–	–	–	6 800
Nitric Acid Production	–	–	–	2.6	800	–	–	–	800
Adipic Acid Production	–	–	–	2.90	900	–	–	–	900
c. Metal Production	**12 000**	–	–	–	–	–	**3 830**	**2 790**	**18 400**
Iron and Steel Production	7 890	–	–	–	–	–	–	–	7 890
Aluminium Production	3 900	–	–	–	–	–	3 830	–	7 730
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	2 790	2 790
d. Consumption of Halocarbons and SF_6	–	–	–	–	–	**3 100**	**19**	**1 500**	**4 600**
e. Other & Undifferentiated Production	**12 000**	–	–	–	–	–	–	–	**12 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	1.5	460	–	–	–	460
AGRICULTURE	–	1 150	24 200	120	37 000	–	–	–	61 000
a. Enteric Fermentation	–	992	20 800	–	–	–	–	–	20 800
b. Manure Management	–	160	3 300	13	3 900	–	–	–	7 200
c. Agricultural Soils	–	–	–	110	33 000	–	–	–	33 000
Direct Sources	–	–	–	85	26 000	–	–	–	26 000
Indirect Sources	–	–	–	20	7 000	–	–	–	7 000
WASTE	280	1 100	23 000	3	1 000	–	–	–	25 000
a. Solid Waste Disposal on Land	–	1 100	23 000	–	–	–	–	–	23 000
b. Wastewater Handling	–	19	400	3	1 000	–	–	–	1 400
c. Waste Incineration	280	0.3	7	0.2	60	–	–	–	350
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	-85 000	10	210	0.51	160	–	–	–	-85 000
a. Forest Land	-110 000	10	210	0.51	160	–	–	–	-110 000
b. Cropland[2]	16 000	–	–	–	–	–	–	–	16 000
c. Grassland	5 000	–	–	–	–	–	–	–	5 000
d. Wetlands	–	–	–	–	–	–	–	–	–
e. Settlements	6 000	–	–	–	–	–	–	–	6 000

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-7: 1999 Greenhouse Gas Emissions Summary for Canada

	Greenhouse Gases								
GHG Source/Sink Categories	**CO_2**	**CH_4**	**CH_4**	**N_2O**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**TOTAL**
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**543 000**	**4 300**	**91 000**	**170**	**52 000**	**2 500**	**4 300**	**3 600**	**696 000**
ENERGY	**503 000**	**2 000**	**40 000**	**40**	**10 000**	–	–	–	**558 000**
a. Stationary Combustion Sources	**316 000**	**200**	**5 000**	**8**	**2 000**	–	–	–	**323 000**
Electricity and Heat Generation	121 000	3.9	81	2	700	–	–	–	121 000
Fossil Fuel Industries	63 000	100	2 000	1	400	–	–	–	65 000
Petroleum Refining	27 000	0.4	9	0.4	100	–	–	–	27 000
Fossil Fuel Production	35 300	100	2 000	1	300	–	–	–	38 000
Mining	7 390	0.1	3	0.2	50	–	–	–	7 450
Manufacturing Industries	52 400	3	60	2	500	–	–	–	52 900
Iron and Steel	7 210	0.3	6	0.2	60	–	–	–	7 280
Non-Ferrous Metals	3 240	0.06	1	0.05	10	–	–	–	3 260
Chemical	8 410	0.18	3.7	0.1	50	–	–	–	8 460
Pulp and Paper	10 800	2	40	0.9	300	–	–	–	11 100
Cement	3 970	0.07	2	0.05	10	–	–	–	3 990
Other Manufacturing	18 700	0.4	8	0.3	100	–	–	–	18 800
Construction	1 160	0.02	0.4	0.03	10	–	–	–	1 170
Commercial & Institutional	28 700	0.5	10	0.6	200	–	–	–	28 900
Residential	40 500	90	2 000	2	500	–	–	–	43 000
Agriculture & Forestry	2 670	0.04	0.8	0.06	20	–	–	–	2 690
b. Transportation	**172 000**	**30**	**700**	**30**	**9 000**	–	–	–	**180 000**
Domestic Aviation	6 400	0.4	9	0.6	200	–	–	–	6 600
Road Transportation	125 000	14	300	19	5 800	–	–	–	131 000
Light-Duty Gasoline Vehicles	47 200	5.1	110	7.8	2 400	–	–	–	49 700
Light-Duty Gasoline Trucks	33 700	4.7	99	9.3	2 900	–	–	–	36 700
Heavy-Duty Gasoline Vehicles	4 010	0.56	12	0.60	180	–	–	–	4 210
Motorcycles	228	0.18	3.8	0.00	1.4	–	–	–	233
Light-Duty Diesel Vehicles	591	0.02	0.3	0.04	10	–	–	–	605
Light-Duty Diesel Trucks	489	0.01	0.3	0.04	10	–	–	–	500
Heavy-Duty Diesel Vehicles	36 900	2	40	1	300	–	–	–	37 300
Propane & Natural Gas Vehicles	1 450	2	40	0.03	9	–	–	–	1 500
Railways	5 780	0.3	7	2	700	–	–	–	7 000
Domestic Marine	4 650	0.3	7	1	300	–	–	–	5 000
Others	31 000	20	400	5	2 000	–	–	–	30 000
Off-Road Gasoline	5 000	6	100	0.1	30	–	–	–	5 000
Off-Road Diesel	13 000	0.7	10	5	2 000	–	–	–	20 000
Pipelines	12 200	12	260	0.3	100	–	–	–	12 600
c. Fugitive Sources	**14 000**	**1 800**	**38 000**	–	–	–	–	–	**52 800**
Coal Mining	–	50	1 000	–	–	–	–	–	1 000
Oil and Natural Gas	14 000	1 800	37 000	–	–	–	–	–	51 700
Oil	34.4	640	13 000	–	–	–	–	–	13 000
Natural Gas	28	1 100	23 000	–	–	–	–	–	23 000
Venting	7 400	–	–	–	–	–	–	–	7 400
Flaring	6 950	30.4	639	–	–	–	–	–	7 600
INDUSTRIAL PROCESSES	**39 800**	–	–	**8.18**	**2 530**	**2 500**	**4 300**	**3 620**	**52 700**
a. Mineral Production	**9 300**	–	–	–	–	–	–	–	**9 300**
Cement	6 600	–	–	–	–	–	–	–	6 600
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	750	–	–	–	–	–	–	–	750
b. Chemical Industry	**6 800**	–	–	**8.18**	**2 530**	–	–	–	**9 400**
Ammonia Production	6 800	–	–	–	–	–	–	–	6 800
Nitric Acid Production	–	–	–	2.5	790	–	–	–	790
Adipic Acid Production	–	–	–	5.64	1 750	–	–	–	1 750
c. Metal Production	**12 000**	–	–	–	–	–	**4 280**	**2 180**	**18 300**
Iron and Steel Production	7 890	–	–	–	–	–	–	–	7 890
Aluminium Production	3 900	–	–	–	–	–	4 280	–	8 210
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	2 180	2 180
d. Consumption of Halocarbons and SF_6	–	–	–	–	–	**2 500**	**19**	**1 400**	**3 900**
e. Other & Undifferentiated Production	**12 000**	–	–	–	–	–	–	–	**12 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	**1.5**	**460**	–	–	–	**460**
AGRICULTURE	–	**1 160**	**24 300**	**120**	**37 000**	–	–	–	**61 000**
a. Enteric Fermentation	–	**997**	**20 900**	–	–	–	–	–	**20 900**
b. Manure Management	–	**160**	**3 400**	**13**	**3 900**	–	–	–	**7 200**
c. Agricultural Soils	–	–	–	**110**	**33 000**	–	–	–	**33 000**
Direct Sources	–	–	–	85	26 000	–	–	–	26 000
Indirect Sources	–	–	–	20	6 000	–	–	–	6 000
WASTE	**280**	**1 100**	**23 000**	**3**	**1 000**	–	–	–	**24 000**
a. Solid Waste Disposal on Land	–	**1 100**	**22 000**	–	–	–	–	–	**22 000**
b. Wastewater Handling	–	**19**	**390**	**3**	**1 000**	–	–	–	**1 300**
c. Waste Incineration	**280**	**0.3**	**7**	**0.2**	**60**	–	–	–	**340**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-69 000**	**39**	**830**	**2.8**	**870**	–	–	–	**-68 000**
a. Forest Land	**-96 000**	**39**	**830**	**2.8**	**870**	–	–	–	**-94 000**
b. Cropland[2]	**16 000**	–	–	–	–	–	–	–	**16 000**
c. Grassland	**5 000**	–	–	–	–	–	–	–	**5 000**
d. Wetlands	–	–	–	–	–	–	–	–	-
e. Settlements	**6 000**	–	–	–	–	–	–	–	**6 000**

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-8: 1998 Greenhouse Gas Emissions Summary for Canada

	Greenhouse Gases								
GHG Source/Sink Categories	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			21		310				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**528 000**	**4 300**	**90 000**	**170**	**54 000**	**1 900**	**4 700**	**3 400**	**682 000**
ENERGY	**488 000**	**2 000**	**40 000**	40	**10 000**	–	–	–	**543 000**
a. **Stationary Combustion Sources**	**306 000**	**200**	**4 000**	**8**	**2 000**	–	–	–	**313 000**
Electricity and Heat Generation	123 000	3.9	82	2	700	–	–	–	124 000
Fossil Fuel Industries	54 000	90	2 000	1	400	–	–	–	57 000
Petroleum Refining	27 000	0.4	9	0.4	100	–	–	–	27 000
Fossil Fuel Production	27 400	90	2 000	0.8	300	–	–	–	30 000
Mining	7 960	0.2	3	0.2	60	–	–	–	8 020
Manufacturing Industries	52 000	3	60	2	500	–	–	–	52 600
Iron and Steel	6 940	0.3	5	0.2	60	–	–	–	7 000
Non-Ferrous Metals	3 390	0.07	1	0.05	20	–	–	–	3 410
Chemical	8 520	0.18	3.7	0.2	50	–	–	–	8 570
Pulp and Paper	10 900	2	40	0.8	300	–	–	–	11 100
Cement	3 270	0.07	1	0.04	10	–	–	–	3 290
Other Manufacturing	19 100	0.4	8	0.3	100	–	–	–	19 200
Construction	1 110	0.02	0.4	0.03	10	–	–	–	1 120
Commercial & Institutional	27 000	0.5	10	0.6	200	–	–	–	27 200
Residential	38 400	90	2 000	2	500	–	–	–	41 000
Agriculture & Forestry	2 590	0.04	0.8	0.06	20	–	–	–	2 610
b. **Transportation**	**168 000**	**40**	**700**	**30**	**9 000**	–	–	–	**180 000**
Domestic Aviation	6 300	0.4	9	0.6	200	–	–	–	6 500
Road Transportation	121 000	15	310	19	5 800	–	–	–	127 000
Light-Duty Gasoline Vehicles	47 100	5.5	120	8.0	2 500	–	–	–	49 700
Light-Duty Gasoline Trucks	29 900	4.5	93	8.7	2 700	–	–	–	32 700
Heavy-Duty Gasoline Vehicles	5 240	0.74	15	0.78	240	–	–	–	5 500
Motorcycles	227	0.18	3.8	0.00	1.4	–	–	–	232
Light-Duty Diesel Vehicles	583	0.02	0.3	0.04	10	–	–	–	597
Light-Duty Diesel Trucks	445	0.01	0.3	0.03	10	–	–	–	455
Heavy-Duty Diesel Vehicles	35 200	2	40	1	300	–	–	–	35 600
Propane & Natural Gas Vehicles	1 730	2	40	0.03	10	–	–	–	1 800
Railways	5 460	0.3	6	2	700	–	–	–	6 000
Domestic Marine	4 830	0.4	8	1	300	–	–	–	5 100
Others	31 000	20	400	6	2 000	–	–	–	30 000
Off-Road Gasoline	6 000	6	100	0.10	40	–	–	–	6 000
Off-Road Diesel	13 000	0.7	10	5	2 000	–	–	–	10 000
Pipelines	12 100	12	260	0.3	100	–	–	–	12 500
c. **Fugitive Sources**	**14 000**	**1 800**	**39 000**	–	–	–	–	–	**52 400**
Coal Mining	–	60	1 000	–	–	–	–	–	1 000
Oil and Natural Gas	14 000	1 800	37 000	–	–	–	–	–	51 000
Oil	39.1	660	14 000	–	–	–	–	–	14 000
Natural Gas	27	1 100	23 000	–	–	–	–	–	23 000
Venting	7 200	–	–	–	–	–	–	–	7 200
Flaring	6 550	28.9	607	–	–	–	–	–	7 200
INDUSTRIAL PROCESSES	**39 500**	–	–	**18.8**	**5 840**	**1 900**	**4 700**	**3 360**	**55 300**
a. **Mineral Production**	**9 900**	–	–	–	–	–	–	–	**9 900**
Cement	6 400	–	–	–	–	–	–	–	6 400
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	1 700	–	–	–	–	–	–	–	1 700
b. **Chemical Industry**	**6 600**	–	–	**18.8**	**5 840**	–	–	–	**12 000**
Ammonia Production	6 600	–	–	–	–	–	–	–	6 600
Nitric Acid Production	–	–	–	2.5	770	–	–	–	770
Adipic Acid Production	–	–	–	16.3	5 070	–	–	–	5 070
c. **Metal Production**	**12 000**	–	–	–	–	–	**4 680**	**1 900**	**18 100**
Iron and Steel Production	7 690	–	–	–	–	–	–	–	7 690
Aluminium Production	3 900	–	–	–	–	–	4 680	–	8 550
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	1 900	1 900
d. **Consumption of Halocarbons and SF_6**	–	–	–	–	–	**1 900**	**19**	**1 500**	**3 300**
e. **Other & Undifferentiated Production**	**11 000**	–	–	–	–	–	–	–	**11 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	**1.5**	**450**	–	–	–	**450**
AGRICULTURE	–	**1 170**	**24 500**	**120**	**36 000**	–	–	–	**60 000**
a. **Enteric Fermentation**	–	**1 000**	**21 100**	–	–	–	–	–	**21 100**
b. **Manure Management**	–	**160**	**3 400**	**13**	**3 900**	–	–	–	**7 300**
c. **Agricultural Soils**	–	–	–	**100**	**32 000**	–	–	–	**32 000**
Direct Sources	–	–	–	82	25 000	–	–	–	25 000
Indirect Sources	–	–	–	20	6 000	–	–	–	6 000
WASTE	**280**	**1 100**	**22 000**	**3**	**1 000**	–	–	–	**24 000**
a. **Solid Waste Disposal on Land**	–	**1 000**	**22 000**	–	–	–	–	–	**22 000**
b. **Wastewater Handling**	–	**19**	**390**	**3**	**900**	–	–	–	**1 300**
c. **Waste Incineration**	**280**	**0.3**	**7**	**0.2**	**60**	–	–	–	**340**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-64 000**	**87**	**1 800**	**6.7**	**2 100**	–	–	–	**-60 000**
a. **Forest Land**	**-90 000**	**87**	**1 800**	**6.7**	**2 100**	–	–	–	**-86 000**
b. **Cropland**[2]	**17 000**	–	–	–	–	–	–	–	**17 000**
c. **Grassland**	**5 000**	–	–	–	–	–	–	–	**5 000**
d. **Wetlands**	–	–	–	–	–	–	–	–	-
e. **Settlements**	**6 000**	–	–	–	–	–	–	–	**6 000**

1 National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

2 CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-9: 1997 Greenhouse Gas Emissions Summary for Canada

	Greenhouse Gases								
GHG Source/Sink Categories	**CO_2**	**CH_4**	**CH_4**	**N_2O**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**TOTAL**
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**517 000**	**4 300**	**90 000**	**190**	**59 000**	**1 400**	**4 900**	**2 900**	**675 000**
ENERGY	**479 000**	**2 000**	**40 000**	**40**	**10 000**	–	–	–	**534 000**
a. Stationary Combustion Sources	**301 000**	**200**	**4 000**	**7**	**2 000**	–	–	–	**307 000**
Electricity and Heat Generation	111 000	3.2	67	2	600	–	–	–	111 000
Fossil Fuel Industries	49 000	80	2 000	1	300	–	–	–	51 000
Petroleum Refining	27 000	0.4	9	0.3	100	–	–	–	27 000
Fossil Fuel Production	22 200	80	2 000	0.7	200	–	–	–	24 000
Mining	8 900	0.2	4	0.2	60	–	–	–	8 970
Manufacturing Industries	54 200	3	60	2	500	–	–	–	54 800
Iron and Steel	7 230	0.3	5	0.2	60	–	–	–	7 300
Non-Ferrous Metals	3 170	0.06	1	0.05	10	–	–	–	3 180
Chemical	8 830	0.18	3.9	0.2	50	–	–	–	8 890
Pulp and Paper	11 700	2	40	0.9	300	–	–	–	12 000
Cement	3 230	0.06	1	0.04	10	–	–	–	3 250
Other Manufacturing	20 000	0.4	8	0.4	100	–	–	–	20 100
Construction	1 250	0.02	0.4	0.03	10	–	–	–	1 260
Commercial & Institutional	29 800	0.5	10	0.6	200	–	–	–	30 000
Residential	43 800	90	2 000	2	500	–	–	–	46 000
Agriculture & Forestry	2 920	0.04	0.9	0.07	20	–	–	–	2 940
b. Transportation	**164 000**	**30**	**700**	**30**	**9 000**	–	–	–	**170 000**
Domestic Aviation	6 160	0.4	9	0.6	200	–	–	–	6 400
Road Transportation	120 000	15	320	19	5 900	–	–	–	126 000
Light-Duty Gasoline Vehicles	47 400	6.0	130	8.4	2 600	–	–	–	50 100
Light-Duty Gasoline Trucks	29 100	4.6	97	8.9	2 800	–	–	–	31 900
Heavy-Duty Gasoline Vehicles	4 820	0.68	14	0.71	220	–	–	–	5 050
Motorcycles	216	0.17	3.6	0.00	1.3	–	–	–	220
Light-Duty Diesel Vehicles	586	0.02	0.3	0.04	10	–	–	–	600
Light-Duty Diesel Trucks	494	0.01	0.3	0.04	10	–	–	–	505
Heavy-Duty Diesel Vehicles	35 200	2	40	1	300	–	–	–	35 500
Propane & Natural Gas Vehicles	1 790	2	40	0.04	10	–	–	–	1 800
Railways	5 660	0.3	7	2	700	–	–	–	6 000
Domestic Marine	4 220	0.3	6	1	300	–	–	–	4 500
Others	29 000	20	400	5	2 000	–	–	–	30 000
Off-Road Gasoline	4 000	5	100	0.09	30	–	–	–	4 000
Off-Road Diesel	13 000	0.6	10	5	2 000	–	–	–	10 000
Pipelines	12 200	12	260	0.3	100	–	–	–	12 600
c. Fugitive Sources	**14 000**	**1 900**	**39 000**	–	–	–	–	–	**52 800**
Coal Mining	–	80	2 000	–	–	–	–	–	2 000
Oil and Natural Gas	14 000	1 800	38 000	–	–	–	–	–	51 200
Oil	35.8	690	14 000	–	–	–	–	–	14 000
Natural Gas	27	1 100	23 000	–	–	–	–	–	23 000
Venting	6 900	–	–	–	–	–	–	–	6 900
Flaring	6 640	29.3	614	–	–	–	–	–	7 300
INDUSTRIAL PROCESSES	**38 000**	–	–	**34.4**	**10 700**	**1 400**	**4 900**	**2 930**	**57 900**
a. Mineral Production	**8 400**	–	–	–	–	–	–	–	**8 400**
Cement	6 200	–	–	–	–	–	–	–	6 200
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	370	–	–	–	–	–	–	–	370
b. Chemical Industry	**6 700**	–	–	**34.4**	**10 700**	–	–	–	**17 000**
Ammonia Production	6 700	–	–	–	–	–	–	–	6 700
Nitric Acid Production	–	–	–	2.5	790	–	–	–	790
Adipic Acid Production	–	–	–	31.9	9 890	–	–	–	9 890
c. Metal Production	**11 000**	–	–	–	–	–	**4 880**	**1 620**	**17 900**
Iron and Steel Production	7 550	–	–	–	–	–	–	–	7 550
Aluminium Production	3 800	–	–	–	–	–	4 880	–	8 720
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	1 620	1 620
d. Consumption of Halocarbons and SF_6	–	–	–	–	–	**1 400**	**19**	**1 300**	**2 800**
e. Other & Undifferentiated Production	**11 000**	–	–	–	–	–	–	–	**11 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	**1.5**	**450**	–	–	–	**450**
AGRICULTURE	–	**1 180**	**24 900**	**110**	**35 000**	–	–	–	**60 000**
a. Enteric Fermentation	–	**1 030**	**21 500**	–	–	–	–	–	**21 500**
b. Manure Management	–	**160**	**3 300**	**13**	**3 900**	–	–	–	**7 300**
c. Agricultural Soils	–	–	–	**100**	**31 000**	–	–	–	**31 000**
Direct Sources	–	–	–	80	25 000	–	–	–	25 000
Indirect Sources	–	–	–	20	7 000	–	–	–	7 000
WASTE	**280**	**1 000**	**22 000**	**3**	**1 000**	–	–	–	**23 000**
a. Solid Waste Disposal on Land	–	**1 000**	**21 000**	–	–	–	–	–	**21 000**
b. Wastewater Handling	–	**18**	**390**	**3**	**900**	–	–	–	**1 300**
c. Waste Incineration	**280**	**0.3**	**7**	**0.2**	**60**	–	–	–	**340**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-100 000**	**27**	**570**	**1.9**	**580**	–	–	–	**-100 000**
a. Forest Land	**-130 000**	**27**	**570**	**1.9**	**580**	–	–	–	**-130 000**
b. Cropland[2]	**17 000**	–	–	–	–	–	–	–	**17 000**
c. Grassland	**5 000**	–	–	–	–	–	–	–	**5 000**
d. Wetlands	–	–	–	–	–	–	–	–	-
e. Settlements	**6 000**	–	–	–	–	–	–	–	**6 000**

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-10: 1996 Greenhouse Gas Emissions Summary for Canada

GHG Source/Sink Categories	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			21		310				
Unit	kt	kt	kt CO_2 eq	kt	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq
TOTAL	**505 000**	**4 300**	**89 000**	**190**	**60 000**	**870**	**5 040**	**2 700**	**663 000**
ENERGY	**468 000**	**2 000**	**40 000**	**40**	**10 000**	–	–	–	**522 000**
a. Stationary Combustion Sources	**296 000**	**200**	**4 000**	**7**	**2 000**	–	–	–	**302 000**
Electricity and Heat Generation	99 000	2.6	55	2	600	–	–	–	99 700
Fossil Fuel Industries	53 000	80	2 000	1	400	–	–	–	55 000
Petroleum Refining	29 000	0.5	10	0.5	100	–	–	–	29 000
Fossil Fuel Production	24 600	80	2 000	0.8	200	–	–	–	27 000
Mining	8 680	0.2	4	0.2	60	–	–	–	8 740
Manufacturing Industries	54 300	3	60	2	500	–	–	–	54 800
Iron and Steel	7 260	0.3	5	0.2	60	–	–	–	7 330
Non-Ferrous Metals	3 490	0.07	1	0.05	20	–	–	–	3 500
Chemical	8 740	0.18	3.8	0.2	50	–	–	–	8 800
Pulp and Paper	11 900	2	40	0.8	300	–	–	–	12 200
Cement	3 250	0.07	1	0.04	10	–	–	–	3 270
Other Manufacturing	19 600	0.4	8	0.3	100	–	–	–	19 700
Construction	1 260	0.02	0.4	0.03	10	–	–	–	1 270
Commercial & Institutional	29 400	0.5	10	0.6	200	–	–	–	29 600
Residential	47 100	90	2 000	2	500	–	–	–	50 000
Agriculture & Forestry	2 930	0.04	0.9	0.07	20	–	–	–	2 950
b. Transportation	**158 000**	**30**	**700**	**30**	**9 000**	–	–	–	**170 000**
Domestic Aviation	5 960	0.4	9	0.6	200	–	–	–	6 200
Road Transportation	114 000	15	320	19	5 800	–	–	–	120 000
Light-Duty Gasoline Vehicles	47 200	6.5	140	8.5	2 600	–	–	–	49 900
Light-Duty Gasoline Trucks	27 100	4.6	96	8.6	2 700	–	–	–	29 900
Heavy-Duty Gasoline Vehicles	4 760	0.67	14	0.71	220	–	–	–	4 990
Motorcycles	205	0.16	3.5	0.00	1.2	–	–	–	210
Light-Duty Diesel Vehicles	589	0.02	0.3	0.04	10	–	–	–	603
Light-Duty Diesel Trucks	393	0.01	0.2	0.03	9	–	–	–	402
Heavy-Duty Diesel Vehicles	32 100	2	30	0.9	300	–	–	–	32 500
Propane & Natural Gas Vehicles	1 930	2	40	0.04	10	–	–	–	2 000
Railways	5 580	0.3	6	2	700	–	–	–	6 000
Domestic Marine	4 160	0.3	6	1	300	–	–	–	4 500
Others	28 000	20	400	5	2 000	–	–	–	30 000
Off-Road Gasoline	5 000	5	100	0.1	30	–	–	–	5 000
Off-Road Diesel	12 000	0.6	10	5	1 000	–	–	–	10 000
Pipelines	12 200	12	250	0.3	100	–	–	–	12 500
c. Fugitive Sources	**13 000**	**1 900**	**39 000**	–	–	–	–	–	**52 700**
Coal Mining	–	80	2 000	–	–	–	–	–	2 000
Oil and Natural Gas	13 000	1 800	37 000	–	–	–	–	–	51 000
Oil	30.7	650	14 000	–	–	–	–	–	14 000
Natural Gas	27	1 100	23 000	–	–	–	–	–	23 000
Venting	6 900	–	–	–	–	–	–	–	6 900
Flaring	6 570	28.9	608	–	–	–	–	–	7 200
INDUSTRIAL PROCESSES	**37 500**	–	–	39.6	12 300	870	5 040	2 700	**58 400**
a. Mineral Production	**8 100**	–	–	–	–	–	–	–	**8 100**
Cement	6 000	–	–	–	–	–	–	–	6 000
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	340	–	–	–	–	–	–	–	340
b. Chemical Industry	**6 500**	–	–	**39.6**	**12 300**	–	–	–	**19 000**
Ammonia Production	6 500	–	–	–	–	–	–	–	6 500
Nitric Acid Production	–	–	–	2.6	790	–	–	–	790
Adipic Acid Production	–	–	–	37.0	11 500	–	–	–	11 500
c. Metal Production	**12 000**	–	–	–	–	–	**5 020**	**1 600**	**18 200**
Iron and Steel Production	7 740	–	–	–	–	–	–	–	7 740
Aluminium Production	3 800	–	–	–	–	–	5 020	–	8 810
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	1 600	1 600
d. Consumption of Halocarbons and SF_6	–	–	–	–	–	**870**	**22**	**1 100**	**2 000**
e. Other & Undifferentiated Production	**11 000**	–	–	–	–	–	–	–	**11 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	1.4	450	–	–	–	**450**
AGRICULTURE	–	1 180	24 700	110	35 000	–	–	–	**60 000**
a. Enteric Fermentation	–	**1 020**	**21 300**	–	–	–	–	–	**21 300**
b. Manure Management	–	**160**	**3 400**	**13**	**3 900**	–	–	–	**7 300**
c. Agricultural Soils	–	–	–	**100**	**31 000**	–	–	–	**31 000**
Direct Sources	–	–	–	81	25 000	–	–	–	25 000
Indirect Sources	–	–	–	20	6 000	–	–	–	6 000
WASTE	**270**	**990**	**21 000**	**3**	**1 000**	–	–	–	**22 000**
a. Solid Waste Disposal on Land	–	**970**	**20 000**	–	–	–	–	–	**20 000**
b. Wastewater Handling	–	**18**	**380**	**3**	**900**	–	–	–	**1 300**
c. Waste Incineration	**270**	**0.3**	**7**	**0.2**	**60**	–	–	–	**340**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-91 000**	**48**	**1 000**	**3.3**	**1 000**	–	–	–	**-89 000**
a. Forest Land	**-120 000**	**48**	**1 000**	**3.3**	**1 000**	–	–	–	**-120 000**
b. Cropland[2]	**18 000**	–	–	–	–	–	–	–	**18 000**
c. Grassland	**5 000**	–	–	–	–	–	–	–	**5 000**
d. Wetlands	–	–	–	–	–	–	–	–	–
e. Settlements	**6 000**	–	–	–	–	–	–	–	**6 000**

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-11: 1995 Greenhouse Gas Emissions Summary for Canada

GHG Source/Sink Categories	Greenhouse Gases CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			21		310				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**492 000**	**4 100**	**87 000**	**190**	**58 000**	**480**	**5 550**	**3 600**	**646 000**
ENERGY	**456 000**	**2 000**	**40 000**	**40**	**10 000**	–	–	–	**508 000**
a. Stationary Combustion Sources	**288 000**	**200**	**4 000**	**7**	**2 000**	–	–	–	**295 000**
Electricity and Heat Generation	100 000	3.0	63	2	600	–	–	–	101 000
Fossil Fuel Industries	53 000	80	2 000	1	400	–	–	–	55 000
Petroleum Refining	28 000	0.5	10	0.5	100	–	–	–	28 000
Fossil Fuel Production	24 300	80	2 000	0.8	200	–	–	–	26 000
Mining	7 800	0.2	3	0.2	60	–	–	–	7 860
Manufacturing Industries	52 500	3	60	2	500	–	–	–	53 100
Iron and Steel	6 980	0.3	5	0.2	60	–	–	–	7 040
Non-Ferrous Metals	3 090	0.06	1	0.04	10	–	–	–	3 110
Chemical	8 410	0.17	3.6	0.1	50	–	–	–	8 460
Pulp and Paper	11 400	2	40	0.8	300	–	–	–	11 700
Cement	3 400	0.07	1	0.05	10	–	–	–	3 420
Other Manufacturing	19 300	0.4	8	0.3	100	–	–	–	19 400
Construction	1 170	0.02	0.4	0.03	10	–	–	–	1 180
Commercial & Institutional	28 800	0.5	10	0.6	200	–	–	–	29 000
Residential	42 400	100	2 000	2	500	–	–	–	45 000
Agriculture & Forestry	2 770	0.04	0.9	0.07	20	–	–	–	2 790
b. Transportation	**155 000**	**30**	**700**	**30**	**9 000**	–	–	–	**160 000**
Domestic Aviation	5 750	0.4	9	0.6	200	–	–	–	5 900
Road Transportation	112 000	16	340	19	5 900	–	–	–	119 000
Light-Duty Gasoline Vehicles	48 400	7.1	150	9.0	2 800	–	–	–	51 400
Light-Duty Gasoline Trucks	25 700	4.5	95	8.4	2 600	–	–	–	28 400
Heavy-Duty Gasoline Vehicles	4 540	0.64	13	0.67	210	–	–	–	4 760
Motorcycles	210	0.17	3.5	0.00	1.3	–	–	–	214
Light-Duty Diesel Vehicles	581	0.02	0.3	0.04	10	–	–	–	594
Light-Duty Diesel Trucks	407	0.01	0.2	0.03	9	–	–	–	417
Heavy-Duty Diesel Vehicles	30 500	1	30	0.9	300	–	–	–	30 800
Propane & Natural Gas Vehicles	2 050	2	40	0.04	10	–	–	–	2 100
Railways	5 710	0.3	7	2	700	–	–	–	6 000
Domestic Marine	4 060	0.3	6	1.0	300	–	–	–	4 400
Others	27 000	20	300	5	2 000	–	–	–	30 000
Off-Road Gasoline	4 000	4	90	0.08	30	–	–	–	4 000
Off-Road Diesel	11 000	0.6	10	5	1 000	–	–	–	10 000
Pipelines	11 700	12	240	0.3	100	–	–	–	12 000
c. Fugitive Sources	**13 000**	**1 800**	**37 000**	–	–	–	–	–	**49 800**
Coal Mining	–	80	2 000	–	–	–	–	–	2 000
Oil and Natural Gas	13 000	1 700	35 000	–	–	–	–	–	48 100
Oil	29.4	600	13 000	–	–	–	–	–	13 000
Natural Gas	26	1 000	22 000	–	–	–	–	–	22 000
Venting	6 700	–	–	–	–	–	–	–	6 700
Flaring	6 250	27.7	582	–	–	–	–	–	6 800
INDUSTRIAL PROCESSES	**36 100**	–	–	**37.1**	**11 500**	**480**	**5 550**	**3 630**	**57 300**
a. Mineral Production	**8 100**	–	–	–	–	–	–	–	**8 100**
Cement	5 900	–	–	–	–	–	–	–	5 900
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	360	–	–	–	–	–	–	–	360
b. Chemical Industry	**6 500**	–	–	**37.1**	**11 500**	–	–	–	**18 000**
Ammonia Production	6 500	–	–	–	–	–	–	–	6 500
Nitric Acid Production	–	–	–	2.5	780	–	–	–	780
Adipic Acid Production	–	–	–	34.6	10 700	–	–	–	10 700
c. Metal Production	**11 000**	–	–	–	–	–	**5 520**	**2 110**	**19 100**
Iron and Steel Production	7 880	–	–	–	–	–	–	–	7 880
Aluminium Production	3 600	–	–	–	–	–	5 520	–	9 090
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	2 110	2 110
d. Consumption of Halocarbons and SF_6	–	–	–	–	–	**480**	**28**	**1 500**	**2 000**
e. Other & Undifferentiated Production	**10 000**	–	–	–	–	–	–	–	**10 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	**1.4**	**440**	–	–	–	**440**
AGRICULTURE	–	**1 170**	**24 600**	**110**	**34 000**	–	–	–	**58 000**
a. Enteric Fermentation	–	**1 010**	**21 300**	–	–	–	–	–	**21 300**
b. Manure Management	–	**160**	**3 400**	**12**	**3 900**	–	–	–	**7 200**
c. Agricultural Soils	–	–	–	**96**	**30 000**	–	–	–	**30 000**
Direct Sources	–	–	–	77	24 000	–	–	–	24 000
Indirect Sources	–	–	–	20	6 000	–	–	–	6 000
WASTE	**270**	**990**	**21 000**	**3**	**1 000**	–	–	–	**22 000**
a. Solid Waste Disposal on Land	–	**970**	**20 000**	–	–	–	–	–	**20 000**
b. Wastewater Handling	–	**18**	**380**	**3**	**900**	–	–	–	**1 300**
c. Waste Incineration	**270**	**0.3**	**7**	**0.2**	**60**	–	–	–	**330**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**950**	**150**	**3 200**	**11**	**3 500**	–	–	–	**7 600**
a. Forest Land	**-28 000**	**150**	**3 200**	**11**	**3 500**	–	–	–	**-22 000**
b. Cropland[2]	**19 000**	–	–	–	–	–	–	–	**19 000**
c. Grassland	**5 000**	–	–	–	–	–	–	–	**5 000**
d. Wetlands	–	–	–	–	–	–	–	–	-
e. Settlements	**6 000**	–	–	–	–	–	–	–	**6 000**

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agricultural soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-12: 1994 Greenhouse Gas Emissions Summary for Canada

GHG Source/Sink Categories	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			21		310				
Unit	kt	kt	kt CO_2 eq	kt	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq
TOTAL	**480 000**	**4 000**	**84 000**	**180**	**57 000**	–	**5 450**	**4 100**	**630 000**
ENERGY	**444 000**	**2 000**	**40 000**	**30**	**10 000**	–	–	–	**494 000**
a. Stationary Combustion Sources	**281 000**	**200**	**4 000**	**7**	**2 000**	–	–	–	**287 000**
Electricity and Heat Generation	95 800	2.6	54	2	600	–	–	–	96 400
Fossil Fuel Industries	51 000	80	2 000	1	400	–	–	–	53 000
Petroleum Refining	27 000	0.4	9	0.4	100	–	–	–	27 000
Fossil Fuel Production	24 300	80	2 000	0.7	200	–	–	–	26 000
Mining	7 440	0.2	3	0.2	50	–	–	–	7 490
Manufacturing Industries	51 900	3	60	2	500	–	–	–	52 400
Iron and Steel	7 400	0.3	6	0.2	60	–	–	–	7 470
Non-Ferrous Metals	3 290	0.07	2	0.05	20	–	–	–	3 310
Chemical	8 480	0.18	3.7	0.1	50	–	–	–	8 530
Pulp and Paper	11 700	2	40	0.8	200	–	–	–	12 000
Cement	3 260	0.07	1	0.04	10	–	–	–	3 280
Other Manufacturing	17 700	0.4	7	0.3	100	–	–	–	17 800
Construction	1 390	0.02	0.5	0.03	10	–	–	–	1 400
Commercial & Institutional	27 300	0.5	10	0.6	200	–	–	–	27 400
Residential	43 700	100	2 000	2	500	–	–	–	46 000
Agriculture & Forestry	2 540	0.04	0.8	0.06	20	–	–	–	2 560
b. Transportation	**151 000**	**30**	**700**	**30**	**8 000**	–	–	–	**160 000**
Domestic Aviation	5 290	0.4	8	0.5	200	–	–	–	5 500
Road Transportation	110 000	16	340	18	5 700	–	–	–	116 000
Light-Duty Gasoline Vehicles	49 400	7.6	160	8.9	2 800	–	–	–	52 300
Light-Duty Gasoline Trucks	24 800	4.5	95	7.9	2 400	–	–	–	27 400
Heavy-Duty Gasoline Vehicles	4 280	0.60	13	0.64	200	–	–	–	4 490
Motorcycles	217	0.17	3.6	0.00	1.3	–	–	–	222
Light-Duty Diesel Vehicles	604	0.02	0.4	0.04	10	–	–	–	618
Light-Duty Diesel Trucks	423	0.01	0.2	0.03	10	–	–	–	432
Heavy-Duty Diesel Vehicles	28 200	1	30	0.8	300	–	–	–	28 500
Propane & Natural Gas Vehicles	1 870	2	40	0.04	10	–	–	–	1 900
Railways	6 310	0.3	7	3	800	–	–	–	7 000
Domestic Marine	4 350	0.3	7	1.0	300	–	–	–	4 700
Others	25 000	20	300	5	1 000	–	–	–	30 000
Off-Road Gasoline	4 000	4	90	0.08	30	–	–	–	4 000
Off-Road Diesel	11 000	0.5	10	4	1 000	–	–	–	10 000
Pipelines	10 500	10	220	0.3	90	–	–	–	10 800
c. Fugitive Sources	**12 000**	**1 700**	**35 000**	–	–	–	–	–	**46 600**
Coal Mining	–	80	2 000	–	–	–	–	–	2 000
Oil and Natural Gas	12 000	1 600	33 000	–	–	–	–	–	44 900
Oil	28.2	540	11 000	–	–	–	–	–	11 000
Natural Gas	25	1 000	21 000	–	–	–	–	–	21 000
Venting	6 200	–	–	–	–	–	–	–	6 200
Flaring	5 590	24.9	523	–	–	–	–	–	6 100
INDUSTRIAL PROCESSES	**35 300**	–	–	**37.9**	**11 700**	–	**5 450**	**4 090**	**56 600**
a. Mineral Production	**7 700**	–	–	–	–	–	–	–	**7 700**
Cement	5 600	–	–	–	–	–	–	–	5 600
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	290	–	–	–	–	–	–	–	290
b. Chemical Industry	**5 800**	–	–	**37.9**	**11 700**	–	–	–	**18 000**
Ammonia Production	5 800	–	–	–	–	–	–	–	5 800
Nitric Acid Production	–	–	–	2.5	770	–	–	–	770
Adipic Acid Production	–	–	–	35.4	11 000	–	–	–	11 000
c. Metal Production	**11 000**	–	–	–	–	–	**5 450**	**2 280**	**19 000**
Iron and Steel Production	7 540	–	–	–	–	–	–	–	7 540
Aluminium Production	3 700	–	–	–	–	–	5 450	–	9 170
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	2 280	2 280
d. Consumption of Halocarbons and SF_6	–	–	–	–	–	–	–	**1 800**	**1 800**
e. Other & Undifferentiated Production	**11 000**	–	–	–	–	–	–	–	**11 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	**1.4**	**440**	–	–	–	**440**
AGRICULTURE	–	**1 130**	**23 800**	**110**	**33 000**	–	–	–	**57 000**
a. Enteric Fermentation	–	**979**	**20 600**	–	–	–	–	–	**20 600**
b. Manure Management	–	**150**	**3 200**	**12**	**3 700**	–	–	–	**7 000**
c. Agricultural Soils	–	–	–	**94**	**29 000**	–	–	–	**29 000**
Direct Sources	–	–	–	75	23 000	–	–	–	23 000
Indirect Sources	–	–	–	20	6 000	–	–	–	6 000
WASTE	**270**	**980**	**21 000**	**3**	**1 000**	–	–	–	**22 000**
a. Solid Waste Disposal on Land	–	**970**	**20 000**	–	–	–	–	–	**20 000**
b. Wastewater Handling	–	**18**	**370**	**3**	**900**	–	–	–	**1 300**
c. Waste Incineration	**270**	**0.3**	**6**	**0.2**	**60**	–	–	–	**330**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-110 000**	**36**	**760**	**2.1**	**640**	–	–	–	**-110 000**
a. Forest Land	**-140 000**	**36**	**760**	**2.1**	**640**	–	–	–	**-140 000**
b. Cropland[2]	**20 000**	–	–	–	–	–	–	–	**20 000**
c. Grassland	**5 000**	–	–	–	–	–	–	–	**5 000**
d. Wetlands	–	–	–	–	–	–	–	–	–
e. Settlements	**6 000**	–	–	–	–	–	–	–	**6 000**

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agriculteral soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-13: 1993 Greenhouse Gas Emissions Summary for Canada

	Greenhouse Gases								
GHG Source/Sink Categories	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			21		310				
Unit	kt	kt	kt CO_2 eq	kt	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq
TOTAL	465 000	3 800	81 000	170	52 000	-	5 940	4 200	608 000
ENERGY	431 000	2 000	40 000	30	10 000	-	-	-	478 000
a. Stationary Combustion Sources	275 000	200	4 000	7	2 000	-	-	-	281 000
Electricity and Heat Generation	93 300	2.5	53	2	600	-	-	-	93 900
Fossil Fuel Industries	51 000	80	2 000	1	400	-	-	-	53 000
Petroleum Refining	28 000	0.5	10	0.4	100	-	-	-	28 000
Fossil Fuel Production	22 800	80	2 000	0.7	200	-	-	-	25 000
Mining	7 370	0.2	3	0.2	50	-	-	-	7 420
Manufacturing Industries	48 700	3	50	1	500	-	-	-	49 300
Iron and Steel	6 600	0.3	5	0.2	60	-	-	-	6 660
Non-Ferrous Metals	2 710	0.06	1	0.04	10	-	-	-	2 730
Chemical	7 270	0.15	3.2	0.1	40	-	-	-	7 310
Pulp and Paper	11 900	2	30	0.7	200	-	-	-	12 100
Cement	2 840	0.06	1	0.04	10	-	-	-	2 860
Other Manufacturing	17 500	0.4	8	0.3	100	-	-	-	17 600
Construction	1 370	0.02	0.5	0.03	10	-	-	-	1 390
Commercial & Institutional	27 900	0.5	10	0.6	200	-	-	-	28 100
Residential	42 530	100	2 000	2	500	-	-	-	46 000
Agriculture & Forestry	3 040	0.05	1	0.07	20	-	-	-	3 060
b. Transportation	144 000	30	700	20	6 000	-	-	-	150 000
Domestic Aviation	5 110	0.4	8	0.5	200	-	-	-	5 300
Road Transportation	105 000	16	340	17	5 100	-	-	-	110 000
Light-Duty Gasoline Vehicles	49 100	7.8	160	8.2	2 500	-	-	-	51 800
Light-Duty Gasoline Trucks	23 300	4.3	91	6.9	2 100	-	-	-	25 500
Heavy-Duty Gasoline Vehicles	3 890	0.55	11	0.58	180	-	-	-	4 080
Motorcycles	215	0.17	3.6	0.00	1.3	-	-	-	220
Light-Duty Diesel Vehicles	612	0.02	0.4	0.04	10	-	-	-	626
Light-Duty Diesel Trucks	419	0.01	0.2	0.03	10	-	-	-	429
Heavy-Duty Diesel Vehicles	25 400	1	30	0.7	200	-	-	-	25 700
Propane & Natural Gas Vehicles	1 970	2	40	0.04	10	-	-	-	2 000
Railways	6 090	0.3	7	2	800	-	-	-	7 000
Domestic Marine	4 190	0.3	6	0.9	300	-	-	-	4 500
Others	23 000	10	300	4	1 000	-	-	-	30 000
Off-Road Gasoline	4 000	4	90	0.08	20	-	-	-	4 000
Off-Road Diesel	9 600	0.5	10	4	1 000	-	-	-	10 000
Pipelines	10 100	10	210	0.3	80	-	-	-	10 400
c. Fugitive Sources	11 000	1 600	33 000	-	-	-	-	-	44 400
Coal Mining	-	90	2 000	-	-	-	-	-	2 000
Oil and Natural Gas	11 000	1 500	31 000	-	-	-	-	-	42 500
Oil	27.2	510	11 000	-	-	-	-	-	11 000
Natural Gas	23	950	20 000	-	-	-	-	-	20 000
Venting	5 800	-	-	-	-	-	-	-	5 800
Flaring	5 520	24.6	517	-	-	-	-	-	6 000
INDUSTRIAL PROCESSES	34 400	-	-	31.8	9 860	-	5 940	4 170	54 400
a. Mineral Production	7 100	-	-	-	-	-	-	-	7 100
Cement	5 000	-	-	-	-	-	-	-	5 000
Lime	2 000	-	-	-	-	-	-	-	2 000
Limestone and Soda Ash Use	310	-	-	-	-	-	-	-	310
b. Chemical Industry	5 700	-	-	31.8	9 860	-	-	-	16 000
Ammonia Production	5 700	-	-	-	-	-	-	-	5 700
Nitric Acid Production	-	-	-	2.5	780	-	-	-	780
Adipic Acid Production	-	-	-	29.3	9 080	-	-	-	9 080
c. Metal Production	12 000	-	-	-	-	-	5 940	2 210	20 100
Iron and Steel Production	8 180	-	-	-	-	-	-	-	8 180
Aluminium Production	3 800	-	-	-	-	-	5 940	-	9 700
SF_6 Used in Magnesium Smelters and Casters	-	-	-	-	-	-	-	2 210	2 210
d. Consumption of Halocarbons and SF_6	-	-	-	-	-	-	-	2 000	2 000
e. Other & Undifferentiated Production	9 700	-	-	-	-	-	-	-	9 700
SOLVENT & OTHER PRODUCT USE	-	-	-	1.4	430	-	-	-	430
AGRICULTURE	-	1 080	22 700	100	31 000	-	-	-	54 000
a. Enteric Fermentation	-	931	19 600	-	-	-	-	-	19 600
b. Manure Management	-	150	3 100	12	3 600	-	-	-	6 700
c. Agricultural Soils	-	-	-	89	28 000	-	-	-	28 000
Direct Sources	-	-	-	72	22 000	-	-	-	22 000
Indirect Sources	-	-	-	20	5 000	-	-	-	5 000
WASTE	260	970	20 000	3	1 000	-	-	-	22 000
a. Solid Waste Disposal on Land	-	960	20 000	-	-	-	-	-	20 000
b. Wastewater Handling	-	18	370	3	900	-	-	-	1 300
c. Waste Incineration	260	0.3	7	0.2	60	-	-	-	330
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	-110 000	64	1 300	4.2	1 300	-	-	-	-110 000
a. Forest Land	-140 000	64	1 300	4.2	1 300	-	-	-	-140 000
b. Cropland[2]	21 000	-	-	-	-	-	-	-	21 000
c. Grassland	5 000	-	-	-	-	-	-	-	5 000
d. Wetlands	-	-	-	-	-	-	-	-	-
e. Settlements	6 000	-	-	-	-	-	-	-	6 000

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agriculteral soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-14: 1992 Greenhouse Gas Emissions Summary for Canada

GHG Source/Sink Categories	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
	Greenhouse Gases								
Global Warming Potential			21		310				
Unit	kt	kt	kt CO_2 eq	kt	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq
TOTAL	466 000	3 700	79 000	170	51 000	–	5 960	4 100	606 000
ENERGY	**433 000**	**2 000**	**40 000**	**30**	**9 000**	–	–	–	**478 000**
a. Stationary Combustion Sources	**281 000**	**200**	**4 000**	**7**	**2 000**	–	–	–	**287 000**
Electricity and Heat Generation	102 000	2.3	49	2	600	–	–	–	103 000
Fossil Fuel Industries	50 000	80	2 000	1	400	–	–	–	52 000
Petroleum Refining	27 000	0.4	9	0.4	100	–	–	–	27 000
Fossil Fuel Production	23 200	80	2 000	0.7	200	–	–	–	25 000
Mining	4 860	0.1	2	0.1	30	–	–	–	4 900
Manufacturing Industries	51 200	3	60	2	500	–	–	–	51 800
Iron and Steel	6 650	0.3	5	0.2	60	–	–	–	6 720
Non-Ferrous Metals	2 820	0.06	1	0.04	10	–	–	–	2 830
Chemical	7 410	0.15	3.2	0.1	40	–	–	–	7 450
Pulp and Paper	12 000	2	40	0.8	200	–	–	–	12 200
Cement	2 860	0.06	1	0.04	10	–	–	–	2 870
Other Manufacturing	19 500	0.4	8	0.4	100	–	–	–	19 600
Construction	1 730	0.03	0.6	0.06	20	–	–	–	1 750
Commercial & Institutional	26 900	0.5	10	0.5	200	–	–	–	27 000
Residential	41 000	90	2 000	2	500	–	–	–	43 000
Agriculture & Forestry	3 250	0.05	1	0.08	20	–	–	–	3 270
b. Transportation	**141 000**	**30**	**700**	**20**	**7 000**	–	–	–	**150 000**
Domestic Aviation	5 360	0.4	9	0.5	200	–	–	–	5 500
Road Transportation	103 000	16	340	15	4 600	–	–	–	108 000
Light-Duty Gasoline Vehicles	49 100	8.1	170	7.5	2 300	–	–	–	51 600
Light-Duty Gasoline Trucks	22 030	4.2	88	5.9	1 800	–	–	–	24 000
Heavy-Duty Gasoline Vehicles	3 560	0.50	11.0	0.53	160	–	–	–	3 740
Motorcycles	213	0.17	3.6	0.00	1.3	–	–	–	218
Light-Duty Diesel Vehicles	618	0.02	0.4	0.05	10	–	–	–	633
Light-Duty Diesel Trucks	445	0.01	0.3	0.03	10	–	–	–	456
Heavy-Duty Diesel Vehicles	24 100	1	20	0.7	200	–	–	–	24 300
Propane & Natural Gas Vehicles	2 610	2	50	0.05	20	–	–	–	2 700
Railways	6 120	0.3	7	2	800	–	–	–	7 000
Domestic Marine	4 790	0.4	8	1	300	–	–	–	5 100
Others	22 000	10	300	4	1 000	–	–	–	20 000
Off-Road Gasoline	4 000	4	90	0.08	20	–	–	–	4 000
Off-Road Diesel	8 400	0.4	9	3	1 000	–	–	–	9 000
Pipelines	9 610	9.6	200	0.3	80	–	–	–	9 890
c. Fugitive Sources	**11 000**	**1 500**	**32 000**	–	–	–	–	–	**42 400**
Coal Mining	–	90	2 000	–	–	–	–	–	2 000
Oil and Natural Gas	11 000	1 400	30 000	–	–	–	–	–	40 600
Oil	25.8	500	10 000	–	–	–	–	–	10 000
Natural Gas	21	900	19 000	–	–	–	–	–	19 000
Venting	5 300	–	–	–	–	–	–	–	5 300
Flaring	5 290	23.6	496	–	–	–	–	–	5 800
INDUSTRIAL PROCESSES	**32 700**	–	–	**34.6**	**10 700**	–	**5 960**	**4 140**	**53 600**
a. Mineral Production	**7 000**	–	–	–	–	–	–	–	**7 000**
Cement	4 700	–	–	–	–	–	–	–	4 700
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	460	–	–	–	–	–	–	–	460
b. Chemical Industry	**5 100**	–	–	**34.6**	**10 700**	–	–	–	**16 000**
Ammonia Production	5 100	–	–	–	–	–	–	–	5 100
Nitric Acid Production	–	–	–	2.5	780	–	–	–	780
Adipic Acid Production	–	–	–	32.1	9 950	–	–	–	9 950
c. Metal Production	**12 000**	–	–	–	–	–	**5 960**	**2 400**	**20 100**
Iron and Steel Production	8 500	–	–	–	–	–	–	–	8 500
Aluminium Production	3 200	–	–	–	–	–	5 960	–	9 150
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	2 400	2 400
d. Consumption of Halocarbons and SF_6	–	–	–	–	–	–	–	**1 700**	**1 700**
e. Other & Undifferentiated Production	**9 000**	–	–	–	–	–	–	–	**9 000**
SOLVENT & OTHER PRODUCT USE	–	–	–	**1.4**	**430**	–	–	–	**430**
AGRICULTURE	–	**1 070**	**22 500**	**97**	**30 000**	–	–	–	**53 000**
a. Enteric Fermentation	–	**923**	**19 400**	–	–	–	–	–	**19 400**
b. Manure Management	–	**150**	**3 200**	**12**	**3 600**	–	–	–	**6 700**
c. Agricultural Soils	–	–	–	**86**	**27 000**	–	–	–	**27 000**
Direct Sources	–	–	–	69	21 000	–	–	–	21 000
Indirect Sources	–	–	–	20	5 000	–	–	–	5 000
WASTE	**260**	**950**	**20 000**	**3**	**900**	–	–	–	**21 000**
a. Solid Waste Disposal on Land	–	**930**	**20 000**	–	–	–	–	–	**20 000**
b. Wastewater Handling	–	**17**	**360**	**3**	**900**	–	–	–	**1 300**
c. Waste Incineration	**260**	**0.5**	**10**	**0.2**	**50**	–	–	–	**330**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-140 000**	**21**	**430**	**1.1**	**340**	–	–	–	**-140 000**
a. Forest Land	**-170 000**	**21**	**430**	**1.1**	**340**	–	–	–	**-170 000**
b. Cropland[2]	**22 000**	–	–	–	–	–	–	–	**22 000**
c. Grassland	**5 000**	–	–	–	–	–	–	–	**5 000**
d. Wetlands	–	–	–	–	–	–	–	–	–
e. Settlements	**6 000**	–	–	–	–	–	–	–	**6 000**

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agriculteral soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-15: 1991 Greenhouse Gas Emissions Summary for Canada

	Greenhouse Gases								
GHG Source/Sink Categories	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			21		310				
Unit	kt	kt	kt CO_2 eq	kt	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq
TOTAL	**451 000**	**3 600**	**75 000**	**160**	**50 000**	**-**	**6 140**	**5 500**	**589 000**
ENERGY	**418 000**	**2 000**	**30 000**	**30**	**9 000**	**-**	**-**	**-**	**461 000**
a. Stationary Combustion Sources	**271 000**	**200**	**4 000**	**7**	**2 000**	**-**	**-**	**-**	**277 000**
Electricity and Heat Generation	96 100	1.7	36	2	500	-	-	-	96 700
Fossil Fuel Industries	48 000	70	2 000	1	300	-	-	-	50 000
Petroleum Refining	26 000	0.4	9	0.4	100	-	-	-	26 000
Fossil Fuel Production	21 900	70	2 000	0.7	200	-	-	-	24 000
Mining	5 040	0.1	2	0.1	30	-	-	-	5 080
Manufacturing Industries	51 900	3	60	2	500	-	-	-	52 400
Iron and Steel	6 390	0.3	5	0.2	60	-	-	-	6 450
Non-Ferrous Metals	2 600	0.06	1	0.0	10	-	-	-	2 610
Chemical	7 440	0.15	3.2	0.1	40	-	-	-	7 480
Pulp and Paper	12 700	2	40	0.8	200	-	-	-	13 000
Cement	2 980	0.06	1	0.04	10	-	-	-	3 000
Other Manufacturing	19 800	0.4	8	0.4	100	-	-	-	19 900
Construction	1 610	0.03	0.6	0.05	20	-	-	-	1 630
Commercial & Institutional	26 300	0.5	10	0.5	200	-	-	-	26 500
Residential	39 800	90	2 000	2	500	-	-	-	42 000
Agriculture & Forestry	2 740	0.04	0.8	0.06	20	-	-	-	2 760
b. Transportation	**137 000**	**30**	**600**	**20**	**6 000**	**-**	**-**	**-**	**140 000**
Domestic Aviation	5 510	0.4	9	0.5	200	-	-	-	5 700
Road Transportation	100 000	16	340	13	4 000	-	-	-	104 000
Light-Duty Gasoline Vehicles	49 000	8.3	170	6.8	2 100	-	-	-	51 300
Light-Duty Gasoline Trucks	20 600	4.0	83	4.9	1 500	-	-	-	22 200
Heavy-Duty Gasoline Vehicles	3 180	0.45	9.4	0.47	150	-	-	-	3 340
Motorcycles	216	0.17	3.6	0.00	1.3	-	-	-	221
Light-Duty Diesel Vehicles	620	0.02	0.4	0.05	10	-	-	-	635
Light-Duty Diesel Trucks	495	0.01	0.3	0.04	10	-	-	-	507
Heavy-Duty Diesel Vehicles	23 600	1	20	0.7	200	-	-	-	23 800
Propane & Natural Gas Vehicles	2 260	2	40	0.04	10	-	-	-	2 300
Railways	5 850	0.3	7	2	700	-	-	-	7 000
Domestic Marine	4 940	0.4	8	1	300	-	-	-	5 200
Others	21 000	10	300	4	1 000	-	-	-	20 000
Off-Road Gasoline	4 000	5	100	0.09	30	-	-	-	5 000
Off-Road Diesel	9 000	0.5	10	4	1 000	-	-	-	10 000
Pipelines	7 430	7.4	160	0.2	60	-	-	-	7 650
c. Fugitive Sources	**10 000**	**1 400**	**30 000**	**-**	**-**	**-**	**-**	**-**	**39 600**
Coal Mining	-	100	2 000	-	-	-	-	-	2 000
Oil and Natural Gas	10 000	1 300	27 000	-	-	-	-	-	37 500
Oil	25.5	440	9 200	-	-	-	-	-	9 200
Natural Gas	20	840	18 000	-	-	-	-	-	18 000
Venting	4 800	-	-	-	-	-	-	-	4 800
Flaring	5 240	23.4	492	-	-	-	-	-	5 700
INDUSTRIAL PROCESSES	**32 900**	**-**	**-**	**34.7**	**10 800**	**-**	**6 140**	**5 450**	**55 200**
a. Mineral Production	**7 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**7 000**
Cement	4 800	-	-	-	-	-	-	-	4 800
Lime	2 000	-	-	-	-	-	-	-	2 000
Limestone and Soda Ash Use	430	-	-	-	-	-	-	-	430
b. Chemical Industry	**4 900**	**-**	**-**	**34.7**	**10 800**	**-**	**-**	**-**	**16 000**
Ammonia Production	4 900	-	-	-	-	-	-	-	4 900
Nitric Acid Production	-	-	-	2.5	770	-	-	-	770
Adipic Acid Production	-	-	-	32.3	10 000	-	-	-	10 000
c. Metal Production	**11 000**	**-**	**-**	**-**	**-**	**-**	**6 140**	**3 590**	**21 000**
Iron and Steel Production	8 320	-	-	-	-	-	-	-	8 320
Aluminium Production	3 000	-	-	-	-	-	6 140	-	9 110
SF_6 Used in Magnesium Smelters and Casters	-	-	-	-	-	-	-	3 590	3 590
d. Consumption of Halocarbons and SF_6	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1 900**	**1 900**
e. Other & Undifferentiated Production	**9 600**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**9 600**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.4**	**420**	**-**	**-**	**-**	**420**
AGRICULTURE	**-**	**1 050**	**22 000**	**96**	**30 000**	**-**	**-**	**-**	**52 000**
a. Enteric Fermentation	**-**	**899**	**18 900**	**-**	**-**	**-**	**-**	**-**	**18 900**
b. Manure Management	**-**	**150**	**3 100**	**11**	**3 500**	**-**	**-**	**-**	**6 600**
c. Agricultural Soils	**-**	**-**	**-**	**84**	**26 000**	**-**	**-**	**-**	**26 000**
Direct Sources	-	-	-	68	21 000	-	-	-	21 000
Indirect Sources	-	-	-	20	5 000	-	-	-	5 000
WASTE	**260**	**930**	**20 000**	**3**	**900**	**-**	**-**	**-**	**21 000**
a. Solid Waste Disposal on Land	**-**	**910**	**19 000**	**-**	**-**	**-**	**-**	**-**	**19 000**
b. Wastewater Handling	**-**	**17**	**360**	**3**	**900**	**-**	**-**	**-**	**1 200**
c. Waste Incineration	**260**	**0.5**	**10**	**0.2**	**50**	**-**	**-**	**-**	**320**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-140 000**	**65**	**1 400**	**4.3**	**1 300**	**-**	**-**	**-**	**-130 000**
a. Forest Land	**-170 000**	**65**	**1 400**	**4.3**	**1 300**	**-**	**-**	**-**	**-170 000**
b. Cropland[2]	**23 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**23 000**
c. Grassland	**5 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**5 000**
d. Wetlands	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Settlements	**6 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**6 000**

1 National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agriculteral soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

2 CO_2 estimates from cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

TABLE A8-16: 1990 Greenhouse Gas Emissions Summary for Canada

GHG Source/Sink Categories	Greenhouse Gases CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			21		310				
Unit	kt	kt	kt CO_2 eq	kt	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq
TOTAL	**460 000**	**3 500**	**73 000**	**170**	**52 000**	**–**	**6 300**	**4 900**	**596 000**
ENERGY	**428 000**	**2 000**	**30 000**	**30**	**8 000**	–	–	–	**469 000**
a. **Stationary Combustion Sources**	**276 000**	**200**	**4 000**	**7**	**2 000**	–	–	–	**282 000**
Electricity and Heat Generation	94 700	1.8	38	2	500	–	–	–	95 300
Fossil Fuel Industries	50 000	80	2 000	1	400	–	–	–	52 000
Petroleum Refining	26 000	0.4	9	0.4	100	–	–	–	26 000
Fossil Fuel Production	23 600	80	2 000	0.7	200	–	–	–	25 000
Mining	6 160	0.1	3	0.1	40	–	–	–	6 200
Manufacturing Industries	54 400	3	60	2	500	–	–	–	54 900
Iron and Steel	6 420	0.2	5	0.2	60	–	–	–	6 490
Non-Ferrous Metals	3 210	0.1	1	0.1	10	–	–	–	3 230
Chemical	7 060	0.15	3.0	0.1	40	–	–	–	7 100
Pulp and Paper	13 400	2	40	0.8	200	–	–	–	13 600
Cement	3 570	0.1	1	0.1	10	–	–	–	3 590
Other Manufacturing	20 700	0.4	9	0.4	100	–	–	–	20 900
Construction	1 860	0.03	0.7	0.1	20	–	–	–	1 880
Commercial & Institutional	25 700	0.5	10	0.5	200	–	–	–	25 800
Residential	41 300	100	2 000	2	500	–	–	–	44 000
Agriculture & Forestry	2 400	0.04	0.8	0.1	20	–	–	–	2 420
b. **Transportation**	**142 000**	**30**	**600**	**20**	**6 000**	–	–	–	**150 000**
Domestic Aviation	6 220	0.5	10	0.6	200	–	–	–	6 400
Road Transportation	103 000	16	350	12	3 600	–	–	–	107 000
Light-Duty Gasoline Vehicles	51 600	9.0	190	6.3	2 000	–	–	–	53 800
Light-Duty Gasoline Trucks	20 300	4.0	83	4.2	1 300	–	–	–	21 700
Heavy-Duty Gasoline Vehicles	2 990	0.42	8.8	0.44	140	–	–	–	3 140
Motorcycles	225	0.18	3.8	0.00	1.4	–	–	–	230
Light-Duty Diesel Vehicles	657	0.02	0.4	0.1	10	–	–	–	672
Light-Duty Diesel Trucks	578	0.02	0.3	0.04	10	–	–	–	591
Heavy-Duty Diesel Vehicles	24 300	1	30	0.7	200	–	–	–	24 500
Propane & Natural Gas Vehicles	2 160	2	40	0.04	10	–	–	–	2 200
Railways	6 320	0.3	7	3	800	–	–	–	7 000
Domestic Marine	4 730	0.4	7	1	300	–	–	–	5 000
Others	22 000	10	300	4	1 000	–	–	–	20 000
Off-Road Gasoline	5 000	6	100	0.1	30	–	–	–	5 000
Off-Road Diesel	10 000	0.5	10	4	1 000	–	–	–	10 000
Pipelines	6 700	6.7	140	0.2	60	–	–	–	6 900
c. **Fugitive Sources**	**9 800**	**1 300**	**28 000**	–	–	–	–	–	**37 900**
Coal Mining	–	90	2 000	–	–	–	–	–	2 000
Oil and Natural Gas	9 800	1 200	26 000	–	–	–	–	–	36 000
Oil	26.9	410	8 500	–	–	–	–	–	8 600
Natural Gas	19	820	17 000	–	–	–	–	–	17 000
Venting	4 500	–	–	–	–	–	–	–	4 500
Flaring	5 290	23.6	496	–	–	–	–	–	5 800
INDUSTRIAL PROCESSES	**31 700**	–	–	**37.1**	**11 500**	–	**6 300**	**4 900**	**54 400**
a. **Mineral Production**	**7 800**	–	–	–	–	–	–	–	**7 800**
Cement	5 600	–	–	–	–	–	–	–	5 600
Lime	2 000	–	–	–	–	–	–	–	2 000
Limestone and Soda Ash Use	440	–	–	–	–	–	–	–	440
b. **Chemical Industry**	**5 000**	–	–	**37.1**	**11 500**	–	–	–	**17 000**
Ammonia Production	5 000	–	–	–	–	–	–	–	5 000
Nitric Acid Production	–	–	–	2.5	780	–	–	–	780
Adipic Acid Production	–	–	–	34.6	10 700	–	–	–	10 700
c. **Metal Production**	**9 700**	–	–	–	–	–	**6 300**	**3 110**	**19 100**
Iron and Steel Production	7 060	–	–	–	–	–	–	–	7 060
Aluminium Production	2 600	–	–	–	–	–	6 300	–	8 930
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	3 110	3 110
d. **Consumption of Halocarbons and SF_6**	–	–	–	–	–	–	–	**1 800**	**1 800**
e. **Other & Undifferentiated Production**	**9 200**	–	–	–	–	–	–	–	**9 200**
SOLVENT & OTHER PRODUCT USE	–	–	–	**1.3**	**420**	–	–	–	**420**
AGRICULTURE	–	**1 040**	**21 800**	**98**	**30 000**	–	–	–	**52 000**
a. **Enteric Fermentation**	–	**890**	**18 700**	–	–	–	–	–	**18 700**
b. **Manure Management**	–	**150**	**3 100**	**11**	**3 500**	–	–	–	**6 600**
c. **Agricultural Soils**	–	–	–	**87**	**27 000**	–	–	–	**27 000**
Direct Sources	–	–	–	70	22 000	–	–	–	22 000
Indirect Sources	–	–	–	20	5 000	–	–	–	5 000
WASTE	**250**	**900**	**19 000**	**3**	**900**	–	–	–	**20 000**
a. **Solid Waste Disposal on Land**	–	**880**	**19 000**	–	–	–	–	–	**19 000**
b. **Wastewater Handling**	–	**17**	**360**	**3**	**900**	–	–	–	**1 200**
c. **Waste Incineration**	**250**	**0.4**	**9**	**0.2**	**50**	–	–	–	**320**
LAND USE, LAND-USE CHANGE AND FORESTRY[1]	**-160 000**	**40**	**830**	**2.3**	**730**	–	–	–	**-150 000**
a. **Forest Land**	**-190 000**	**40**	**830**	**2.3**	**730**	–	–	–	**-190 000**
b. **Cropland**[2]	**23 000**	–	–	–	–	–	–	–	**23 000**
c. **Grassland**	**5 000**	–	–	–	–	–	–	–	**5 000**
d. **Wetlands**	–	–	–	–	–	–	–	–	–
e. **Settlements**	**6 000**	–	–	–	–	–	–	–	**6 000**

[1] National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector. CO_2 from agriculteral soils and non-CO_2 emissions from forest fires, which were previously included in national totals, are now excluded.

[2] CO_2 estimates from Cropland include about 16 Mt CO_2 of annual emissions due to land conversion to cropland.

Note: Totals may not add due to rounding.

ANNEX 9: ELECTRICITY INTENSITY TABLES

Detailed GHG information for the electricity sector is presented for the complete time series within the following tables by region and by generation source. The purpose of these tables is to provide additional trends information on utility and industrial generated intensity value, electricity generation, and emission data. The information presented in this annex excludes the emissions associated with heat generation. Information on the contribution of emissions from the electricity and heat generation sector is presented in "Canada's Greenhouse Gas Emission Tables, 1990–2003" (Annex 8) and "Provincial/Territorial Greenhouse Gas Emission Trends, 1990–2003" (Annex 12).

National-level trends analysis for the electricity sector is covered in the "Emission Trends" (Section 2.3.1.1, Emissions from Fuel Combustion) and the "Energy" (Section 3.1.1, Energy Industries) chapters of this report.

The electricity intensity values were derived for each fuel type using GHG emission estimates and electricity generation data. The methodology used to develop the GHG emissions is discussed in the Energy Industries section (Section 3.1.1) and in Annex 2 (Methodology and Data for Estimating Emissions from Fuel Combustion) of this report. Electricity generation data are from Statistics Canada's RESD (Statistics Canada, #53-007).

TABLE A9-1: Electricity Generation and Greenhouse Gas Emission Details for Canada[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
							Greenhouse Gas Emissions *kt CO_2 eq*							
Coal	78 800	82 500	85 400	78 200	81 700	83 100	84 800	91 400	97 500	96 700	104 800	103 400	101 900	101 400
Refined Petroleum Products[2]	11 400	9 590	10 500	7 780	6 040	6 990	5 620	8 110	11 900	9 600	8 800	10 600	8 500	10 200
Natural Gas	4 050	3 530	5 850	6 860	7 020	9 150	7 770	9 670	11 800	12 400	16 100	17 100	15 600	16 900
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Others[5]	404	428	512	462	652	522	346	1 100	1 080	1 230	1 260	1 380	1 470	3 880
Total	**94 600**	**96 000**	**102 000**	**93 300**	**95 400**	**99 700**	**98 600**	**110 000**	**122 000**	**120 000**	**131 000**	**132 000**	**128000**	**132 000**
							Electricity Generation[a] *GWh*							
Coal	76 794	82 592	84 024	76 863	80 837	81 563	83 981	92 903	99 914	100 528	109 895	110 026	109 391	105 317
Refined Petroleum Products[2]	14 388	12 195	13 454	9 995	7 765	9 390	7 855	11 169	16 105	13 239	12 339	14 547	12 372	15 690
Natural Gas	9 018	8 054	12 258	14 291	15 406	19 784	17 150	20 031	24 692	25 961	31 678	34 054	32 042	33 625
Nuclear	68 761	80 123	76 019	88 639	101 711	92 306	87 510	77 857	67 466	69 331	68 674	72 320	71 252	70 293
Hydro[3]	293 985	305 323	313 325	320 445	326 699	332 705	352 183	347 274	328 706	342 167	354 812	329 881	346 917	334 560
Biomass[4]	3 546	3 562	3 992	4 303	5 142	5 049	5 233	5 651	5 810	6 388	6 372	6 795	7 138	6 948
Others[5]	1 118	1 195	1 318	1 439	1 899	1 946	1 909	1 199	1 172	2 323	2 045	1 799	1 987	1 404
Total	**467 609**	**493 043**	**504 391**	**515 974**	**539 458**	**542 744**	**555 822**	**556 084**	**543 865**	**559 937**	**585 816**	**569 422**	**581 097**	**567 836**
							Greenhouse Gas Intensity[7] *g CO_2 eq/kWh*							
Coal	1 030	1 000	1 020	1 020	1 010	1 020	1 010	980	980	960	950	940	930	960
Refined Petroleum Products[2]	792	786	780	779	778	745	715	726	737	720	710	730	690	650
Natural Gas	449	439	478	480	455	463	453	483	476	478	508	501	487	503
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Others[5,6]	362	358	388	321	343	268	181	920	921	531	615	766	740	2 760
Average Intensity	**202**	**195**	**203**	**181**	**177**	**184**	**177**	**198**	**225**	**214**	**223**	**233**	**219**	**233**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A9-2: Electricity Generation and Greenhouse Gas Emission Details for Newfoundland and Labrador[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
							Greenhouse Gas Emissions *kt CO_2 eq*							
Coal	0	0	0	0	0	0	0	0	0	0	0	X	X	X
Refined Petroleum Products[2]	1 610	1 280	1 480	1 340	720	1 250	1 160	1 210	1 020	810	800	X	X	X
Natural Gas	0	0	0	0	0	0	0	0	0	124	115	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5]	0	0	0	0	0	0	0	0	0	0	0	X	X	X
Total	**1 610**	**1 280**	**1 480**	**1 340**	**720**	**1 250**	**1 160**	**1 210**	**1 020**	**940**	**920**	**X**	**X**	**X**
							Electricity Generation[a] *GWh*							
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	1 978	1 534	1 784	1 659	879	1 626	1 484	1 573	1 317	971	1 025	2 155	2 436	2 008
Natural Gas	0	0	0	0	0	0	0	0	164	283	261	273	273	284
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	34 687	35 410	34 875	39 194	37 606	36 287	35 292	40 177	43 640	41 382	42 313	38 824	41 416	39 801
Biomass[4]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**36 665**	**36 944**	**36 659**	**40 853**	**38 485**	**37 913**	**36 776**	**41 750**	**45 121**	**42 636**	**43 599**	**41 252**	**44 125**	**42 093**
							Greenhouse Gas Intensity[7] *g CO_2 eq/kWh*							
Coal	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Refined Petroleum Products[2]	816	835	829	809	815	770	782	770	772	836	785	X	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	440	440	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Average Intensity	**44.0**	**34.7**	**40.3**	**32.9**	**18.6**	**33.0**	**31.6**	**29.0**	**22.5**	**21.9**	**21.1**	**X**	**X**	**X**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

X Denotes confidential values.

TABLE A9-3: Electricity Generation and Greenhouse Gas Emission Details for Prince Edward Island[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
							Greenhouse Gas Emissions kt CO_2 eq							
Coal	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Refined Petroleum Products[2]	101	90.6	50.2	73.3	57.3	37.5	24.3	30.6	10.2	18.5	54.9	X	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Total	**101**	**90.6**	**50.2**	**73.3**	**57.3**	**37.5**	**24.3**	**30.6**	**10.2**	**18.5**	**54.9**	**X**	**X**	**X**
							Electricity Generation[a] GWh							
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	80.5	71.6	34.0	58.8	40.5	22.6	10.5	22.0	3.5	9.8	49.1	43.0	20.3	43.2
Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass[4]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**80.5**	**71.6**	**34.0**	**58.8**	**40.5**	**22.6**	**10.5**	**22.0**	**3.5**	**9.8**	**49.1**	**43.0**	**20.3**	**43.2**
							Greenhouse Gas Intensity[7] g CO_2 eq/kWh							
Coal	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Refined Petroleum Products[2]	1250	1270	1480	1250	1410	1660	2320	1390	2910	1890	1120	X	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Average Intensity	**1250**	**1270**	**1480**	**1250**	**1410**	**1660**	**2320**	**1390**	**2910**	**1890**	**1120**	**X**	**X**	**X**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.
2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.
3 Emissions from the flooding of land for hydro dams are not included.
4 Emissions related to the use of biomass for electric power generation are not included.
5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.
6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.
7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.
X Denotes confidential values.

TABLE A9-4: Electricity Generation and Greenhouse Gas Emission Details for Nova Scotia[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Greenhouse Gas Emissions *kt CO_2 eq*														
Coal	5 050	5 280	5 390	5 530	6 100	5 840	6 510	6 860	5 890	6 530	7 590	X	X	X
Refined Petroleum Products[2]	1 790	1 720	1 990	1 770	1 020	1 050	600	680	1 920	1 520	1 230	X	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5]	0	0	0	0	0	0	0	0	0	0	0	X	X	X
Total	**6 830**	**7 000**	**7 380**	**7 310**	**7 120**	**6 900**	**7 100**	**7 530**	**7 800**	**8 060**	**8 820**	**X**	**X**	**X**
Electricity Generation[a] *GWh*														
Coal	5 760	5 933	6 079	6 337	7 136	6 987	7 944	8 367	7 119	7 916	8 959	9 801	8 576	8 745
Refined Petroleum Products[2]	2 233	2 113	2 447	2 201	1 290	1 407	791	887	2 475	1 978	1 547	1 106	424	2 184
Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0	1 930	157
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	1 181	1 071	905	916	1 054	937	1 156	978	932	1 018	924	748	1 082	1 142
Biomass[4]	259	277	290	260	287	240	302	281	235	158	191	189	127	198
Others[5]	0	0	0	0	0	0	0	0	19	6	4	5	8	0
Total	**9 432**	**9 394**	**9 720**	**9 714**	**9 767**	**9 571**	**10 193**	**10 513**	**10 780**	**11 076**	**11 624**	**11 849**	**12 146**	**12 425**
Greenhouse Gas Intensity[7] *g CO_2 eq/kWh*														
Coal	880	890	890	870	860	840	820	820	830	830	850	X	X	X
Refined Petroleum Products[2]	800	813	813	805	788	749	753	761	775	770	790	X	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Average Intensity	**724**	**745**	**759**	**752**	**729**	**721**	**697**	**717**	**724**	**727**	**759**	**X**	**X**	**X**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

X Denotes confidential values.

TABLE A9-5: Electricity Generation and Greenhouse Gas Emission Details for New Brunswick[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Greenhouse Gas Emissions *kt CO_2 eq*														
Coal	1 140	940	1 030	1 190	2 680	3 040	3 150	3 030	3 240	3 130	2 820	X	X	X
Refined Petroleum Products[2]	4 700	4 320	4 950	3 830	3 280	3 560	2 670	5 090	5 970	4 820	5 550	X	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Total	**5 840**	**5 270**	**5 980**	**5 010**	**5 960**	**6 600**	**5 820**	**8 120**	**9 210**	**7 950**	**8 360**	**X**	**X**	**X**
Electricity Generation[a] *GWh*														
Coal	1 285	1 120	1 226	1 377	3 118	3 445	3 551	3 625	3 901	3 885	3 607	3 849	3 462	3 684
Refined Petroleum Products[2]	6 092	5 718	6 477	4 931	4 249	4 538	3 308	6 564	7 687	6 415	7 586	8 455	7 184	5 579
Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0	245	1 166
Nuclear	5 338	5 440	4 833	5 323	5 239	1 579	4 591	3 444	3 773	4 083	3 959	4 487	3 757	4 742
Hydro[3]	3 533	3 003	3 011	3 057	2 773	2 706	3 532	2 373	2 862	3 380	3 293	2 059	2 251	3 233
Biomass[4]	505	527	462	471	516	520	507	779	815	910	847	871	974	914
Others[5]	0	0	0	0	0	0	0	0	0	2	3	8	10	9
Total	**16 752**	**15 808**	**16 009**	**15 158**	**15 895**	**12 788**	**15 488**	**16 784**	**19 038**	**18 676**	**19 295**	**19 728**	**17 883**	**19 328**
Greenhouse Gas Intensity[7] *g CO_2 eq/kWh*														
Coal	880	840	840	860	860	880	890	840	830	810	780	X	X	X
Refined Petroleum Products[2]	772	756	764	776	772	784	806	775	777	750	730	X	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Average Intensity	**348**	**333**	**374**	**331**	**375**	**516**	**376**	**484**	**484**	**426**	**433**	**X**	**X**	**X**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.
2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.
3 Emissions from the flooding of land for hydro dams are not included.
4 Emissions related to the use of biomass for electric power generation are not included.
5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.
6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.
7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.
X Denotes confidential values.

TABLE A9-6: Electricity Generation and Greenhouse Gas Emission Details for Quebec[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
							Greenhouse Gas Emissions kt CO_2 eq							
Coal	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Refined Petroleum Products[2]	1 360	374	794	144	310	188	184	215	1 330	910	310	340	240	1 500
Natural Gas	75.0	75.0	75.0	75.0	82.0	80.0	81.0	81.0	76.0	63.0	72.0	68.0	72.0	73.0
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	**1 430**	**448**	**869**	**219**	**392**	**268**	**265**	**296**	**1 400**	**980**	**380**	**410**	**310**	**1 580**
							Electricity Generation[a] GWh							
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	1 707	415	1 015	166	247	370	556	695	2 329	1 753	869	1 047	894	3 777
Natural Gas	156	123	145	140	105	268	385	392	252	244	332	358	428	267
Nuclear	4 070	3 910	4 600	4 807	5 406	4 511	5 243	4 204	3 814	3 775	4 886	4 705	4 530	3 548
Hydro[3]	129 939	138 550	141 983	150 048	157 851	167 946	165 016	160 686	148 148	162 890	173 179	164 529	170 713	170 949
Biomass[4]	0	0	0	0	0	0	185	273	403	506	478	485	584	617
Others[5]	11	0	0	0	0	4	1	5	4	8	13	7	0	0
Total	**135 883**	**142 998**	**147 743**	**155 160**	**163 609**	**173 099**	**171 386**	**166 255**	**154 950**	**169 176**	**179 757**	**171 131**	**177 150**	**179 158**
							Greenhouse Gas Intensity[7] g CO_2 eq/kWh							
Coal	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Refined Petroleum Products[2]	795	900	782	869	1 260	508	331	309	569	520	360	330	270	400
Natural Gas	482	607	519	538	776	300	210	206	302	259	217	189	168	275
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Average Intensity	**10.5**	**3.1**	**5.9**	**1.4**	**2.4**	**1.6**	**1.6**	**1.8**	**9.0**	**5.8**	**2.1**	**2.4**	**1.8**	**8.8**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.
2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.
3 Emissions from the flooding of land for hydro dams are not included.
4 Emissions related to the use of biomass for electric power generation are not included.
5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.
6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.
7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A9-7: Electricity Generation and Greenhouse Gas Emission Details for Ontario[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
							Greenhouse Gas Emissions *kt CO₂ eq*							
Coal	24 800	26 200	25 400	16 500	13 500	14 300	16 400	20 600	27 200	28 200	36 200	33 300	33 100	32 900
Refined Petroleum Products[2]	1 130	934	710	139	278	348	308	356	1 210	1 060	400	690	500	1 110
Natural Gas	528	554	1 270	1 550	1 900	3 750	3 650	4 290	4 500	5 620	5 460	6 040	6 160	6 600
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Others[5]	25.6	55.8	61.4	69.9	78.0	79.3	85.9	329	235	264	223	186	283	249
Total	**26 400**	**27 700**	**27 400**	**18 300**	**15 800**	**18 500**	**20 500**	**25 600**	**33 100**	**35 200**	**42 300**	**40 200**	**40 100**	**40 800**
							Electricity Generation[a] *GWh*							
Coal	26 121	30 298	28 221	19 452	16 377	16 677	19 515	26 310	34 096	34 809	42 447	38 236	37 951	35 902
Refined Petroleum Products[2]	1 377	1 238	894	169	378	508	519	547	1 657	1 525	583	982	762	1 441
Natural Gas	1 597	1 683	2 996	3 545	4 302	7 750	7 892	8 874	9 838	12 143	11 283	12 216	12 959	13 450
Nuclear	59 353	70 773	66 586	78 509	91 066	86 216	77 676	70 209	59 879	61 473	59 829	63 128	62 965	62 003
Hydro[3]	40 561	37 647	40 151	40 753	39 311	38 809	41 662	39 963	35 416	37 294	37 908	37 136	38 438	36 067
Biomass[4]	657	611	761	687	792	860	790	918	947	922	972	964	1 020	881
Others[5]	108	194	180	195	203	199	219	221	262	228	204	194	240	227
Total	**129 773**	**142 444**	**139 788**	**143 310**	**152 430**	**151 018**	**148 271**	**147 041**	**142 094**	**148 392**	**153 221**	**152 856**	**154 336**	**149 970**
							Greenhouse Gas Intensity[7] *g CO₂ eq/kWh*							
Coal	948	865	899	848	826	859	841	782	797	811	852	871	872	916
Refined Petroleum Products[2]	824	754	794	822	735	686	594	652	728	690	690	700	660	770
Natural Gas	330	329	424	438	442	484	463	483	458	463	484	495	475	490
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Others[5,6]	238	287	342	359	384	399	393	1 490	899	1 160	1 090	957	1 180	1 100
Average Intensity	**204**	**195**	**196**	**127**	**104**	**123**	**138**	**174**	**233**	**237**	**276**	**263**	**259**	**272**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.
2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.
3 Emissions from the flooding of land for hydro dams are not included.
4 Emissions related to the use of biomass for electric power generation are not included.
5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.
6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.
7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A9-8: Electricity Generation and Greenhouse Gas Emission Details for Manitoba[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
							Greenhouse Gas Emissions *kt CO_2 eq*							
Coal	455	352	351	252	276	180	282	224	944	522	971	X	X	X
Refined Petroleum Products[2]	66.2	64.4	61.4	30.0	45.1	35.2	55.7	20.0	18.3	23.5	21.5	X	X	X
Natural Gas	3.04	2.28	5.16	2.28	1.90	3.62	2.48	0.19	–	–	–	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Total	**525**	**418**	**417**	**284**	**323**	**219**	**340**	**244**	**962**	**546**	**993**	**X**	**X**	**X**
							Electricity Generation[a] *GWh*							
Coal	322	233	237	188	195	128	200	178	844	461	869	443	365	635
Refined Petroleum Products[2]	61	65	57	31	54	57	61	27	25	36	36	45	46	42
Natural Gas	12.9	9.2	13.9	8.9	8.0	14.0	11.0	0.7	0.0	0.0	0.0	0.0	134.4	150.4
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	19 827	22 554	26 434	26 891	28 146	29 013	30 866	33 391	30 781	28 138	31 536	32 899	28 821	20 246
Biomass[4]	31	30	43	40	42	26	45	64	74	56	60	61	72	67
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Total	**20 254**	**22 891**	**26 785**	**27 159**	**28 445**	**29 238**	**31 184**	**33 661**	**31 724**	**28 691**	**32 501**	**33 448**	**29 438**	**21 152**
							Greenhouse Gas Intensity[7] *g CO_2 eq/kWh*							
Coal	1 410	1 510	1 480	1 340	1 420	1 410	1 410	1 260	1 120	1 130	1 120	X	X	X
Refined Petroleum Products[2]	1 080	999	1 080	970	828	616	911	741	733	650	600	X	X	X
Natural Gas	236	248	371	257	238	258	225	272	–	–	–	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Average Intensity	**25.9**	**18.3**	**15.6**	**10.5**	**11.4**	**7.5**	**10.9**	**7.2**	**30.3**	**19.0**	**30.5**	**X**	**X**	**X**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

X Denotes confidential values.

TABLE A9-9: Electricity Generation and Greenhouse Gas Emission Details for Saskatchewan[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
							Greenhouse Gas Emissions *kt CO_2 eq*							
Coal	10 100	10 300	11 600	12 100	13 100	13 400	13 500	14 000	14 100	14 000	13 200	X	X	X
Refined Petroleum Products[2]	22.4	20.5	21.2	19.4	27.8	56.6	62.9	82.1	49.8	50.0	40.0	X	X	X
Natural Gas	260	306	571	268	129	412	419	759	989	880	1 440	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Total	**10 400**	**10 600**	**12 100**	**12 400**	**13 300**	**13 900**	**14 000**	**14 900**	**15 100**	**14 900**	**14 700**	**X**	**X**	**X**
							Electricity Generation[a] *GWh*							
Coal	8 634	8 617	9 889	10 443	11 544	11 258	11 175	11 290	11 622	11 644	11 819	11 756	11 848	11 583
Refined Petroleum Products[2]	47	43	46	41	64	95	95	98	58	59	50	40	37	34
Natural Gas	545	622	1 048	579	374	816	813	1 337	1 725	1 483	2 448	2 678	2 839	4 432
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	4 215	4 214	3 059	4 051	3 393	4 118	4 376	3 987	3 442	3 689	3 046	2 393	2 879	3 475
Biomass[4]	100	102	94	98	103	107	96	126	114	115	125	349	367	265
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**13 541**	**13 598**	**14 137**	**15 212**	**15 479**	**16 394**	**16 554**	**16 837**	**16 961**	**16 988**	**17 488**	**17 215**	**17 970**	**19 789**
							Greenhouse Gas Intensity[7] *g CO_2 eq/kWh*							
Coal	1 170	1 190	1 170	1 160	1 140	1 190	1 210	1 240	1 210	1 200	1 120	X	X	X
Refined Petroleum Products[2]	478	480	459	473	433	594	666	841	853	850	810	X	X	X
Natural Gas	476	492	545	464	345	506	516	568	573	594	590	X	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X	X
Average Intensity	**765**	**780**	**859**	**815**	**857**	**846**	**847**	**882**	**891**	**878**	**840**	**X**	**X**	**X**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.
2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.
3 Emissions from the flooding of land for hydro dams are not included.
4 Emissions related to the use of biomass for electric power generation are not included.
5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.
6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.
7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.
X Denotes confidential values.

TABLE A9-10: Electricity Generation and Greenhouse Gas Emission Details for Alberta[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Greenhouse Gas Emissions *kt CO_2 eq*														
Coal	37 300	39 400	41 700	42 600	46 000	46 300	44 900	46 700	46 200	44 300	44 000	45 200	46 000	45 600
Refined Petroleum Products[2]	12.0	13.7	15.1	17.7	18.0	16.3	42.9	8.00	31.0	30.0	40.0	30.0	30.0	40.0
Natural Gas	2 290	2 040	2 850	2 810	2 790	2 220	2 900	3 350	4 360	4 480	6 550	6 210	5 060	5 250
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5]	334	345	425	392	543	443	260	770	840	970	1 040	1 190	1 190	3 200
Total	**40 000**	**41 800**	**45 000**	**45 800**	**49 300**	**49 000**	**48 100**	**50 800**	**51 400**	**49 800**	**51 700**	**52 600**	**52 300**	**54 100**
Electricity Generation[a] *GWh*														
Coal	34 672	36 391	38 373	39 066	42 467	43 069	41 596	43 134	42 332	41 814	42 199	45 943	47 189	44 768
Refined Petroleum Products[2]	14.0	16.3	17.8	20.9	21.3	19.5	51.5	10	39	33	41	39	37	46
Natural Gas	4 971	4 484	5 960	5 911	6 000	5 111	6 273	6 817	8 816	8 516	12 141	11 969	9 998	10 169
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	2 060	2 030	1 563	1 808	1 806	2 190	1 990	1 837	2 098	2 239	1 845	1 568	1 884	2 162
Biomass[4]	446	557	565	717	771	756	725	828	821	829	778	1 216	1 220	1 236
Others[5]	999	1 001	1 139	1 141	1 295	1 308	1 316	535	315	1 716	1 530	1 303	1 313	1 073
Total	**43 162**	**44 480**	**47 617**	**48 663**	**52 361**	**52 453**	**51 951**	**53 161**	**54 421**	**55 147**	**58 534**	**62 038**	**61 641**	**59 454**
Greenhouse Gas Intensity[7] *g CO_2 eq/kWh*														
Coal	1 080	1 080	1 090	1 090	1 080	1 070	1 080	1 080	1 090	1 060	1 040	980	980	1 020
Refined Petroleum Products[2]	857	841	851	847	845	835	832	792	793	830	850	790	690	820
Natural Gas	461	455	478	475	465	435	463	492	495	526	539	519	506	517
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5,6]	334	345	373	343	419	339	198	1 450	2 680	564	677	915	904	2 980
Average Intensity	**926**	**940**	**946**	**941**	**942**	**934**	**927**	**956**	**944**	**902**	**882**	**848**	**849**	**911**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A9-11: Electricity Generation and Greenhouse Gas Emission Details for British Columbia[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
							Greenhouse Gas Emissions *kt CO_2 eq*							
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	333	532	236	243	118	90.6	135	77.0	76.1	70.0	88.0	108	60.0	80.0
Natural Gas	841	507	1 030	2 100	2 060	2 610	632	1 110	1 770	1 200	2 360	2 920	1 120	1 250
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**1 170**	**1 040**	**1 270**	**2 340**	**2 180**	**2 700**	**770**	**1 190**	**1 840**	**1 270**	**2 450**	**3 030**	**1 180**	**1 330**
							Electricity Generation[a] *GWh*							
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	510	688	391	433	213	169	373	223	141	154	157	204	140	161
Natural Gas	1 647	1 040	1 999	4 012	4 523	5 728	1 675	2 508	3 795	3 190	5 106	6 454	3 126	3 440
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	57 308	60 197	60 663	53 174	54 305	50 181	67 668	63 332	60 860	61 582	60 208	49 162	58 878	56 929
Biomass[4]	1 549	1 458	1 778	2 030	2 630	2 540	2 583	2 383	2 402	2 893	2 921	2 660	2 775	2 771
Others[5]	0	0	0	103	401	436	374	438	573	362	293	283	416	82
Total	**61 015**	**63 383**	**64 831**	**59 753**	**62 071**	**59 054**	**72 673**	**68 884**	**67 771**	**68 182**	**68 684**	**58 763**	**65 335**	**63 383**
							Greenhouse Gas Intensity[7] *g CO_2 eq/kWh*							
Coal	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Refined Petroleum Products[2]	653	773	605	562	555	536	363	346	538	450	560	530	430	500
Natural Gas	510	488	516	523	456	456	378	442	466	376	463	453	359	363
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Average Intensity	**19.2**	**16.4**	**19.6**	**39.2**	**35.1**	**45.7**	**10.6**	**17.2**	**27.2**	**18.6**	**35.7**	**51.6**	**18.1**	**20.9**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A9-12: Electricity Generation and Greenhouse Gas Emission Details for Yukon, Northwest Territories, and Nunavut[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
							Greenhouse Gas Emissions *kt CO_2 eq*							
Coal	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Refined Petroleum Products[2]	262	224	188	176	176	355	378	360	304	273	239	247	198	152
Natural Gas	48.9	50.8	52.5	52.5	50.4	71.1	76.8	77.0	55.5	56.0	71.5	70.1	77.8	82.2
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	**311**	**274**	**240**	**228**	**226**	**426**	**455**	**437**	**360**	**329**	**310**	**317**	**275**	**234**
							Electricity Generation[a] *GWh*							
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	289	293	291	285	330	578	608	524	373	306	396	430	392	375
Natural Gas	89	92	96	96	94	99	103	103	102	103	107	105	108	110
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	674	647	681	553	454	518	625	550	527	555	560	563	555	556
Biomass[4]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**1052**	**1033**	**1068**	**934**	**877**	**1194**	**1335**	**1177**	**1002**	**963**	**1063**	**1099**	**1055**	**1041**
							Greenhouse Gas Intensity[7] *g CO_2 eq/kWh*							
Coal	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Refined Petroleum Products[2]	905	762	646	615	534	614	622	686	816	890	600	570	500	400
Natural Gas	550	550	547	547	539	721	748	747	542	546	668	666	719	747
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Average Intensity	**295**	**266**	**225**	**244**	**258**	**357**	**341**	**371**	**359**	**341**	**292**	**288**	**261**	**255**

Sources:

a Statistics Canada, *Report on Energy Supply – Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 Greenhouse Gas Intensity for Others: emission intensity values are not shown due to the miscellaneous nature of Other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

REFERENCES

Statistics Canada, *Report on Energy Supply–Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

ANNEX 10: ANALYSIS OF EMISSION TRENDS FOR CANADIAN INDUSTRIAL SECTORS

A10.1 INTRODUCTION

This annex discusses and identifies, where data are available, the GHG emission and GDP trends for a series of Canadian industrial sectors. This analysis is different from any presented previously in this document, in that it provides information by industrial sector rather than using the standard IPCC format.

Generally, in this report, information and discussions are separated into the six conventional IPCC source categories: Energy; Industrial Processes; Solvent and Other Product Use; Agriculture; Land Use, Land-Use Change and Forestry; and Waste. This examination of GHG emission trends, however, groups emission data that may otherwise appear in separate IPCC categories into the Canadian industrial sectors in which they occur. That is, for a given industry, fuel combustion emissions, process-related emissions, and fugitive emissions are combined, and total emission values are provided for each sector (see Table A10-1).

Table A10-1 shows emissions from various Canadian industrial sectors for 1990, 2002, and 2003. The Canadian industrial sectors are separated into categories based on NAICS. Energy data are consistent with the NAICS code breakdown used in Statistics Canada's Industrial Consumption of Energy and the RESD (Statistics Canada, #57-003), and, as such, the RESD should be used as a reference to interpret the NAICS groupings. Table A10-2 is a further breakdown of the industrial process emissions included in Table A10-1.

TABLE A10-1: **Industrial GHG Emissions by Fuel Combustion, Process, and Fugitive Sources for 1990, 2002, and 2003**[1]

	Fuel Combustion			Industrial Process (see Table A10-2 for details)			Fugitive Sources			Total			GDP[2]		
	Mt CO_2 eq												*$Million (constant 1997 dollars)*		
Sector	1990	2002	2003	1990	2002	2003	1990	2002	2003	1990	2002	2003	1990	2002	2003
Oil and Gas Industry	**60**	**86**	**82**	**1.9**	**3.8**	**3.9**	**36.0**	**53.5**	**53.0**	**97.5**	**143**	**139**	**22 068**	**31 857**	**32 092**
Upstream Oil and Gas Industry	40	62	59	1.1	2.8	2.7	33	50	50	74	115	111	18 123	26 608	26 855
Oil and Gas Production[3]	33	51	50	1.1	2.8	2.7	29	44	44	63	99	96	15 795	21 805	22 039
Natural Gas Transmission	6.90	11.0	9.11	–	–	–	4.3	5.7	5.7	11.2	16.6	14.8	2 328	4 803	4 546
Downstream Oil and Gas Industry	20	24	24	0.79	1.0	1.2	2.8	3.4	3.4	23	28	28	3 945	5 249	5 237
Petroleum Refining[4]	20	24	24	0.79	1.0	1.2				21	25	25	1 516	1 847	1 828
Natural Gas Distribution							2.8	3.4	3.4	2.8	3.4	3.4	2 429	3 402	3 409
Mining and Manufacturing Industries	**64.2**	**62.3**	**66.4**	**50.7**	**46.1**	**46.5**	**2.2**	**1.0**	**1.0**	**117**	**109**	**114**	**196 711**	**259 507**	**265 521**
Mining[5]	4.97	9.85	13.7	–	–	–	2.2	1.0	1.0	6.88	10.8	14.7	11 126	13 387	15 158
Manufacturing Industries															
Smelting and Refining Industries	3.23	3.22	3.20	13.4	11.2	11.3	–	–	–	16.6	14.4	14.5	3 646	6 933	6 868
Pulp, Paper, and Saw Mills	13.6	9.21	9.13	–	–	–	–	–	–	13.6	9.21	9.13	9 692	11 648	11 741
Primary and Other Steel Industries	6.49	6.49	6.42	7.06	7.11	7.04	–	–	–	13.5	13.6	13.5	4 259	4 920	4 939
Cement	3.59	4.18	4.20	5.6	6.7	6.8	–	–	–	9.2	11	11	703	725	745
Industrial Chemical Industries	7.10	6.13	5.74	21	13	13	–	–	–	28	19	18	4 257	4 879	5 070
Other Manufacturing	20.9	19.9	20.5	2.2	1.9	1.9	–	–	–	23.1	21.8	22.4	93 493	143 044	142 957
Construction, Agriculture, and Forestry	4.30	3.35	3.51	–	–	–	–	–	–	4.30	3.35	3.51	69 535	73 971	78 043
Product Consumption[6]	–	–	–	1.8	6.4	6.9	–	–	–	1.8	6.4	6.9	–	–	–

Notes:

[1] Due to rounding, individual values may not add up to totals.

[2] GDP is reported in millions and in 1997 constant dollars (Informetrica Limited and Statistics Canada).

[3] Includes combustion, process, and fugitive emissions associated with conventional and unconventional production of oil and gas.

[4] Includes combustion and process emissions associated with the refining of crude oil.

[5] A small proportion of emissions from the upstream petroleum industry (NAICS 211) are accounted for in the mining sector due to data limitations.

[6] Emissions from product consumption are, in this document, inventoried under Industrial Processes. However, sources for such emissions tend to be found in all areas — industrial, commercial, and end consumer.

TABLE A10-2: Breakdown of Emissions from Process Sources for 1990, 2002, and 2003[1]

	1990	2002	2003
	Mt CO_2 eq		
Oil and Gas Industry	**1.9**	**3.8**	**3.9**
Upstream Oil and Gas Industry	1.1	2.8	2.7
Downstream Oil and Gas Industry	0.80	1.0	1.2
Mining and Manufacturing Industries	**50.7**	**46.1**	**46.5**
Mining	–	–	–
Smelting and Refining Industries	13.4	11.2	11.3
Aluminium Production	8.93	7.11	7.32
Magnesium Production	2.87	2.68	2.23
Magnesium Casting	0.24	0.23	0.25
Others[2]	1.4	1.2	1.5
Pulp and Paper and Sawmills	–	–	–
Primary & Other Steel Industries	7.06	7.11	7.04
Cement	5.6	6.7	6.8
Industrial Chemical Industries	21	13	13
Ammonia Production	5.0	6.2	6.2
Adipic Acid Production	10.7	1.25	1.09
Nitric Acid Production	0.78	0.81	0.81
Others[3]	4.1	4.4	4.5
Other Manufacturing	2	2	2
Lime Production	2	2	2
Limestone and Soda Ash Use	0.45	0.24	0.24
Product Consumption (all economic sectors)[4]	1.8	6.4	7.0
Consumption of Halocarbons[5]	–	3.10	3.1
Other Refined Petroleum Products (lubricating oils and greases, waxes, etc.)	1.8	3.3	3.8

Notes:

1 Due to rounding, individual values may not add up to totals.

2 Includes process emissions associated with non-energy use of coal, lignite, metallurgical coke, and petroleum coke (less those that have already been accounted for in aluminium production).

3 Includes process emissions associated with non-energy use of NGLs, petrochemical feedstocks, naphtha, and natural gas.

4 Emissions from product consumption are, in this document, inventoried under Industrial Processes. However, sources for such emissions tend to be found in all areas — industrial, commercial, and end consumer.

5 Includes HFCs and PFCs minus those already accounted for in aluminium production.

A10.2 OIL AND GAS INDUSTRY

In 2003, the oil and gas industry as a whole contributed 139 Mt (19%) of Canada's total GHG emissions, of which the upstream subsector and downstream subsector contributed about 111 Mt and 28 Mt, respectively. Emission details for the industry are presented in Tables A10-1 and S-6 (in the Executive Summary section). As a result of growing foreign demand, since 1990, the industry has experienced a 180% rise in net energy exports,[47] with an attendant increase of 25 Mt (115%) in GHG emissions associated only with those exports.

The oil and gas industry showed a 45% growth in economic sector GDP (Informetrica Limited and Statistics Canada) between 1990 and 2003. The upstream oil and gas subsector saw an increase of approximately 48% in economic activity between 1990 and 2003, while the downstream (refining and distribution) subsector's economic growth was about 33%.

In 2003, oil and gas production alone contributed 96 Mt to the inventory, while the transmission of natural gas contributed 14.8 Mt of the emissions attributable to the upstream sector. The refining of petroleum products contributed 25 Mt and fugitive emissions from the distribution of natural gas contributed 3.4 Mt to the downstream sector.

A10.3 MINING

In 2003, the mining industry contributed 14.7 Mt (2%) to Canada's GHG emissions, as shown in Table A10-1.

Between 1990 and 2003, the mining industry observed a 36% increase in sector GDP and emitted 7.8 Mt more GHG emissions, of which 93% were due to stationary combustion of fossil fuels (Informetrica Limited and Statistics Canada). Emissions from stationary combustion activities increased by about 176% (8.7 Mt), due largely to increased demand for natural gas (by 242% or 175 PJ) and NGLs (by 280% or 15 PJ) (Statistics Canada, #57-003).

Fugitive emissions of CH_4 from underground coal mines decreased by 48% between 1990 and 2003, due largely to mine closures in the Maritime provinces.

Note that GHG emissions from the mining industry as discussed and as shown in this annex exclude emissions from the use of natural gas by oil sand operations.

A10.4 SMELTING AND REFINING INDUSTRIES

In 2003, GHG emissions from non-ferrous smelting and refining activities were estimated at 14.5 Mt, or 2% of Canada's national GHG emissions total, as shown in Table A10-1.

Between 1990 and 2003, the non-ferrous smelting and refining industry experienced growth in sector GDP of 88%, while GHG emissions decreased by 13% (Informetrica Limited and Statistics Canada). GHG emissions decreased primarily due to improvements resulting in lower process emissions. There has been little change in the emissions from stationary combustion, which were 3.2 Mt in 2003.

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[47] Net energy exports are the totals of exports minus imports of all oil and gas products.

Between 1990 and 2003, process emissions from primary aluminium production decreased by 18%, while primary aluminium production increased by 78% (NRCan). This reduction in emissions in the aluminium industry can be attributed to better control of the anode events in smelters, through use of electronic monitoring and automated emission controls within existing plants and in new capacity additions. In the same time frame, the production of primary magnesium increased by more than 196% (NRCan), but the emissions from this industry showed a reduction of 22%. This resulted from progressive replacement of SF_6 used as cover gas with alternatives and the shutdown of a magnesium production plant in Quebec. SF_6 emissions from casting facilities remained relatively constant at the 1990 level.

A10.5 PULP, PAPER, AND SAW MILLS

In 2003, stationary fuel combustion from the pulp, paper, and saw mill industry contributed 9.1 Mt (or 1.2%) to Canada's total GHG emissions, as shown in Table A10-1.

Between 1990 and 2003, the industry saw a 4.5 Mt reduction of GHG emissions and a 21% growth in sector GDP (Informetrica Limited and Statistics Canada). A 20% increase in the use of spent pulping liquors[48] combined with reduction in the use of GHG-intensive fossil fuels such as coal and refined petroleum products (decreased by 39%) contributed to an overall emission reduction of 33% (Statistics Canada, #57-003).

A10.6 PRIMARY AND OTHER STEEL INDUSTRIES

In 2003, the primary and other steel industries contributed 13.5 Mt (or 1.8%) to Canada's total GHG emissions (refer to Table A10-1). Stationary fuel combustion and process-related sources accounted for 48% (or 6.4 Mt) and 52% (or 7.0 Mt) of the GHG emissions for the industry, respectively.

Between 1990 and 2003, the industry experienced a 16% growth in sector GDP (Informetrica Limited and Statistics Canada) and a decrease of 0.6% in GHG emissions. Total pig iron and total steel production between 1990 and 2003 increased by 16% and 30%, respectively (Statistics Canada, #41-001). Process emissions from pig iron and raw steel production showed a decrease of 0.2% (or 20 kt), while emissions from stationary combustion for all ferrous metal production decreased by 1.0% (or 100 kt) during this time frame.

A10.7 CEMENT

In 2003, GHG emissions from cement production contributed an estimated 11 Mt (or 1.5%) to Canada's national GHG emission total, as presented in Table A10-1. CO_2 emissions occurring as a result of the clinker production process account for just under two-thirds of the total emissions from the cement industry, while the balance is attributable to fuel combustion.

Over the 1990–2003 period, the cement industry experienced a 20% increase in GHG emissions and a 6% increase in sector GDP (Informetrica Limited and Statistics Canada). Process CO_2 emissions from the production of clinker increased by 22%, while emissions from stationary combustion increased by 17%. Over the same time frame, clinker production increased by 22% (Statistics Canada, #44-001; NRCan).

A10.8 INDUSTRIAL CHEMICAL INDUSTRIES

In 2003, GHG emissions from industrial chemical production were estimated at 18 Mt, or 2.5% of Canada's national GHG emission total, as shown in Table A10-1.

In 2003, the downward trend in GHG emissions from this sector continued. Almost 68% of the GHG emissions from this industry are process emissions, which have decreased about 39% since 1990.

The Canadian chemical industries exhibited a 34% decrease in GHG emissions between 1990 and 2003. From an economic standpoint, since 1990, the Canadian chemical manufacturing industry has continued to expand, with sector GDP growing over 19%. Chemical product demand between 2002 and 2003 increased, resulting in a 4% increase in GDP (Informetrica Limited and Statistics Canada).

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[48] CO_2 resulting from the use of biomass is not included in inventory totals (IPCC/OECD/IEA, 1997).

While production has increased at the sole adipic acid production plant in Canada since 1990, the installation of an emission abatement system at this facility in 1997 resulted in a 9.6 Mt (or 90%) reduction in process-related N_2O emissions over the 1990–2003 period. Conversely, process emissions associated with the production of ammonia and nitric acid increased 23% and 3.7%, respectively, since 1990.

A10.9 OTHER MANUFACTURING

In 2003, "other manufacturing" industries contributed 22.4 Mt of Canada's total GHG emissions; 70% of the emissions were from fuel combustion, and 30% were from process-related activities. "Other manufacturing" industries consist of all other industries that are not specifically listed in this annex, such as the textile industry and the food and beverage production industry.

Process-related emissions from "other manufacturing" industries are from the production of lime and the use of limestone and soda ash. Between 1990 and 2003, a process emission reduction of 6% was observed in the lime industry. Emissions associated with the use of limestone and soda ash decreased by 47% between 1990 and 2003.

A10.10 OTHER INDUSTRIES

The category of "other industries" accounts for GHG emissions from the combustion of fossil fuels for the following three industries:

1) *Construction*: construction of buildings, highways, and construction industry services such as plumbing, carpentry, painting, etc.;
2) *Agriculture*: agriculture, hunting and trapping industry (excluding food processing, farm machinery manufacturing and repairs); and
3) *Forestry*: includes the forestry and logging service industry.

Overall, "other industries" emitted 3.5 Mt of GHGs in 2003. This is a decrease of 18% since 1990. There has been a 12% increase in sector GDP over this time. Over the last year (2002–2003), emissions increased 5%, while GDP increased 5.5%.

In 2003, the construction industry's GHG emissions totalled 1.3 Mt, contributing to less than 1% of the national emissions. Emissions associated with off-road vehicle usage within the construction industry are not included here. They are discussed in the transportation category (see Transport in Section 2.3.1.1).

Between 1990 and 2003, the construction industry's GHG emissions decreased by 18%, while the industry experienced a 12.2% growth in industry GDP (Informetrica Limited and Statistics Canada).

In 2003, low GHG-intensive fossil fuels, such as natural gas, accounted for 78% of the overall fuel mix, relative to 59% in 1990. Also in 2003, refined petroleum products and NGLs contributed 13% and 9% to the overall fuel mix, relative to an 18% and 22% contribution in 1990, respectively (Statistics Canada, #57-003). These changes contributed to the decrease in emissions.

A discussion of the emission trends for stationary fuel combustion-related emissions in the agriculture and forestry industries is available in Section 2.3.1.1 of this report.

A10.11 PRODUCT CONSUMPTION

Product consumption refers to the consumption of products by all markets, including the industrial, commercial, and consumer markets, which results in PFC, CO_2, and HFC emissions. Products resulting in HFC and PFC emissions include refrigerants and propellants, while those resulting in CO_2 emissions include lubricants, waxes, and petroleum-based solvents.

Given that HFCs were used in a negligible amount before 1995 and there has been growing replacement of CFCs with HFCs since 1995, emissions from consumption of halocarbons have increased by 3.1 Mt since 1990. Emissions coming from the use of feedstocks (e.g., lubricants and waxes) have doubled during the period 1990–2003. From 2002 to 2003, these emissions increased by 18%.

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ANNEX 11: PROVINCIAL/TERRITORIAL ANALYSIS

The following discussion describes GHG emission trends for each of the provinces and territories in Canada for both the long term (1990–2003) and the short term (2002–2003). Owing to data limitations — specifically confidentiality — there are a number of caveats associated with the data and with the analysis. While the national inventory of GHG emissions is developed utilizing provincial and territorial information and data, the information used to develop the national estimates relies on survey and sampling data that, while statistically valid and nationally representative, may not represent every discrete and small source within a province or territory. Therefore, the analysis that follows, while reflecting an accurate national picture, may differ slightly from a more bottom-up, precise regional inventory. Nevertheless, the trends in emissions by region provided are considered representative of the emission trends in each region.

All emission references are from the 2003 National GHG Inventory and are given in units of CO_2 equivalent unless otherwise stated. All energy quantities, GDP, and HDD values originate from Statistics Canada (2003). All values provided within these graphs are presented in kilotonnes CO_2 equivalent.

HDDs are an indicator of the necessity for space heating in a region. The number of HDDs is calculated for each day by subtracting the day's mean temperature from a base temperature (usually 18°C). The daily totals are accumulated for each month, and the monthly totals are accumulated for the "heating year" from July through June. The amount of energy consumed for heating is closely correlated to these HDDs. Only one value is given per province/territory per year and, although real, is a weighted average of many weather stations in a province/territory and therefore may not be completely indicative of local conditions; it does, nonetheless, give a relative indication of year-to-year regional heating requirements. Furthermore, as this is a function of weather and climate, a trend may not be indicative of the region's performance with respect to emission mitigation actions.

A11.1 NEWFOUNDLAND AND LABRADOR

In 2003, Newfoundland and Labrador represented 1.6% of Canada's population and generated 1.5% of the GHGs and 1.4% of Canada's total GDP. Combined, these parameters registered GHG emissions of 20.9 t per person and 708 kt per billion dollars GDP (Table A11-1). Since 1990, socioeconomic indicators show a 49.8% increase in total GDP, while population and HDDs show decreases of 10.1% and 0.8%, respectively.

TABLE A11-1: Trends in GHG Emissions and GHG Intensity, Newfoundland and Labrador

	1990	1995	2000	2002	2003
Total GHG (Mt)	**9.34**	**8.13**	**8.63**	**11.3**	**10.9**
Growth Since 1990	N/A	-13%	-7.6%	21%	16%
Annual Change	N/A	13%	-2.6%	20%	-3.6%
GDP Expense – Annual Change	N/A	2.3%	5.8%	15.4%	6.5%
GHG Intensity (Mt/$B GDP)	**0.91**	**0.75**	**0.70**	**0.78**	**0.71**
Annual Change	N/A	10%	-8.0%	3.7%	-9.5%

Emissions from the Energy and Waste sectors account for 95.1% and 4.1%, respectively, of their total regional contribution. Within the Energy Sector, stationary sources comprise 61%, while transportation is responsible for 36%.

A11.1.1 LONG-TERM TRENDS (1990–2003)

Over the long term (1990–2003), Newfoundland and Labrador's GHG emissions increased 17%, from 9.3 to 10.9 Mt. Energy Sector sources were responsible for both the greatest growth and the greatest decline. Increases due to fossil fuel industries (1.4 Mt), off-road fuel use (0.4 Mt), HDDVs (0.2 Mt), LDGTs (0.2 Mt), and fugitive emissions resulting from oil and natural gas production (0.2 Mt) were offset by reductions in domestic marine (0.3 Mt), residential heating (0.2 Mt), mining and manufacturing industries (0.2 Mt), and gasoline automobiles (0.1 Mt).

The 648% increase in energy production (primary) since 1990 has been a major driver of the emissions increase, evidenced by a 132% growth spike in the 1997–1998 period and a further 72% spike between 2001 and 2002 following the ramping up of production from the Hibernia oil field.

Agricultural emissions from enteric fermentation remained unchanged between 1990 and 2003, whereas emissions from manure management and N_2O emissions from cropland soils decreased. Declining swine and poultry populations reduced the emissions from manure management and direct and indirect N_2O emissions from soil.

Long-term emission trends in Newfoundland and Labrador are illustrated in Figure A11-1.

A11.1.2 SHORT-TERM TRENDS (2002–2003)

Over the short term, GHG emissions decreased by 3.6%, primarily as a result of a decline in emissions from the fossil fuel industries.

Short-term emission trends in Newfoundland and Labrador are illustrated in Figure A11-2.

FIGURE A11-1: **Newfoundland and Labrador Long-Term Emission Trends, 1990–2003**

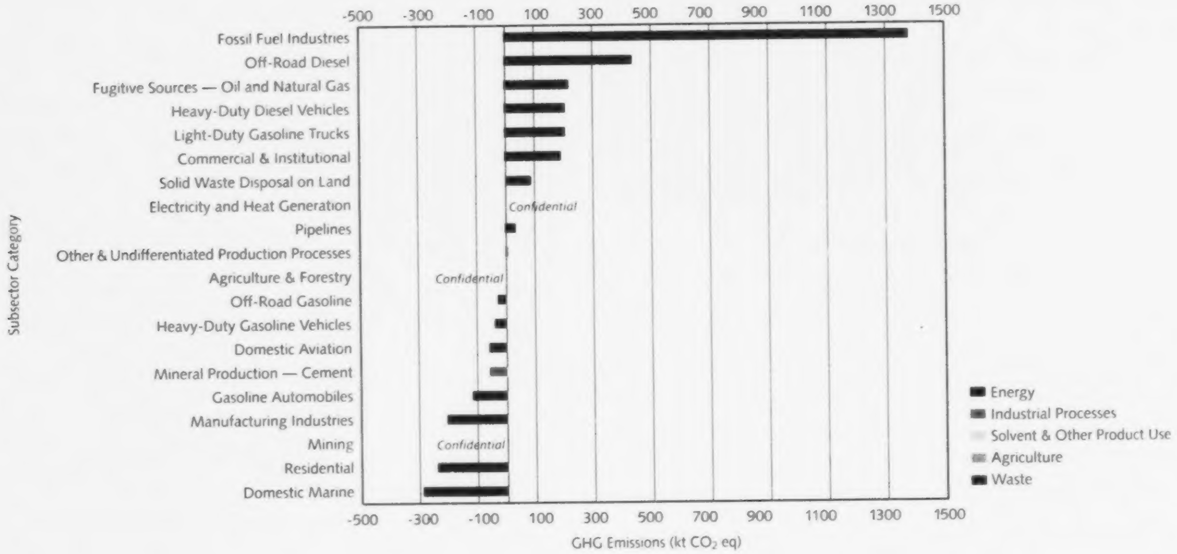
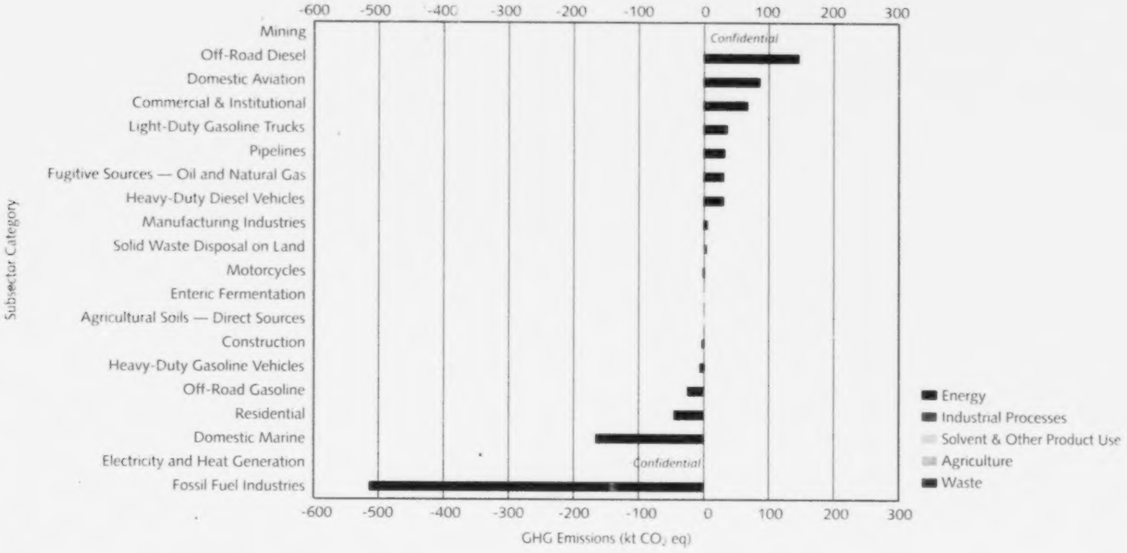


FIGURE A11-2: Newfoundland and Labrador Short-Term Emission Trends, 2002–2003



A11.2 PRINCE EDWARD ISLAND

Prince Edward Island, with 0.4% of Canada's population (137 800), contributed 2.1 Mt (0.3%) and $3.4 billion (0.3%) towards Canada's GHG and GDP totals, respectively, in 2003. These values are up 5.5%, 8.4%, and 45.1%, respectively, since 1990, while GHG emissions increased 4.0% and GDP increased 1.9% since 2002 (Table A11-2).

TABLE A11-2: Trends in GHG Emissions and GHG Intensity, Prince Edward Island

	1990	1995	2000	2002	2003
Total GHG (Mt)	**1.93**	**1.83**	**2.10**	**2.01**	**2.09**
Growth Since 1990	N/A	-5.0%	9.0%	4.2%	8.4%
Annual Change	N/A	-2.1%	7.5%	0.5%	4.0%
GDP Expense – Annual Change	N/A	6.4%	3.0%	5.7%	1.9%
GHG Intensity (Mt/$B GDP)	**0.82**	**0.68**	**0.67**	**0.60**	**0.62**
Annual Change	N/A	-8.0%	4.3%	-4.9%	2.1%

The Energy, Agriculture, and Waste sectors are responsible for over 99% of the province's total emissions, with a relatively larger portion coming from agricultural sources and a relatively smaller portion from the Energy Sector compared with the other Atlantic provinces (18% and 77%, respectively).

A11.2.1 LONG-TERM TRENDS (1990–2003)

The Energy Sector showed an overall long-term increase of 10% (0.1 Mt), resulting from a 30% increase in road transport-related emissions, specifically 87% and 76% increases in the emissions from LDGTs and HDDVs, respectively.

Direct N_2O emissions from cropland soils and indirect N_2O emissions that occur off site fluctuated but generally increased between 1990 and 2003, while emissions from enteric fermentation and manure management declined over this period. Higher synthetic fertilizer consumption increased emissions, while reductions in both dairy and non-dairy cattle populations lowered emissions, even though swine populations increased during the same period.

Long-term emission trends in Prince Edward Island are illustrated in Figure A11-3.

A11.2.2 SHORT-TERM TRENDS (2002–2003)

Overall, emissions of GHGs increased by 4% between 2002 and 2003. This increase was primarily due to an 8.3% increase in emissions from stationary sources and a 2.7% increase from the transportation subsector. The short-term trend between 2002 and

2003 showed no change in N_2O and CH_4 emissions from enteric fermentation, manure management, and agricultural soils.

Short-term emission trends in Prince Edward Island are illustrated in Figure A11-4.

FIGURE A11-3: Prince Edward Island Long-Term Emission Trends, 1990–2003

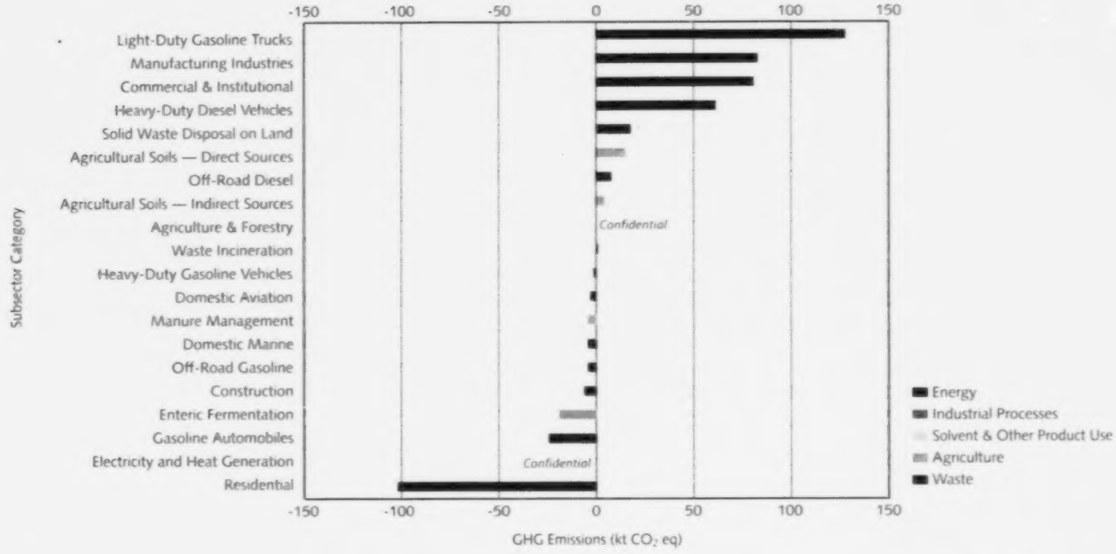
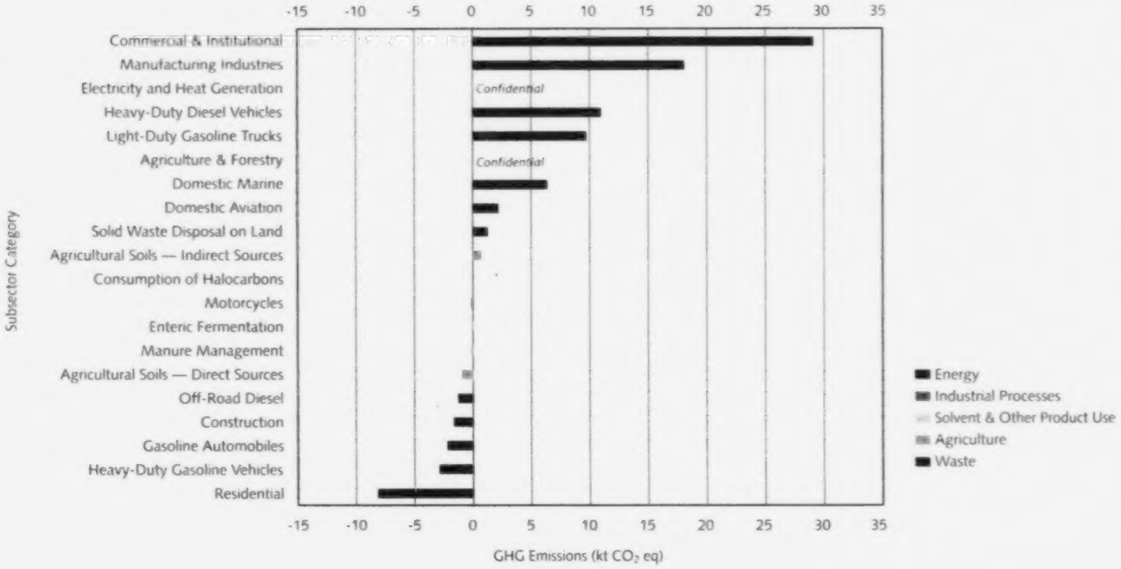


FIGURE A11-4: Prince Edward Island Short-Term Emission Trends, 2002–2003



A11.3 NOVA SCOTIA

In 2003, Nova Scotia generated 21.2 Mt or 2.9% of Canada's total GHGs (Table A11-3). Nova Scotians represent 3.0% of the population and contribute 2.3% to the total GDP. Since 1990, GHGs, population, and GDP output increased 10%, 2.9%, and 33.8%, respectively, while a review of HDDs shows that the year 2003 accumulated 2.0% more than the 1990 "base" year and 0.7% less than 2002.

TABLE A11-3: **Trends in GHG Emissions and GHG Intensity, Nova Scotia**

	1990	1995	2000	2002	2003
Total GHG (Mt)	**19.2**	**18.8**	**21.2**	**19.8**	**21.2**
Growth Since 1990	N/A	-1.8%	10%	3.5%	10%
Annual Change	N/A	-0.6%	5.5%	-2.9%	6.7%
GDP Expense – Annual Change	N/A	1.7%	4.0%	4.4%	0.9%
GHG Intensity (Mt/$B GDP)	**1.02**	**0.97**	**0.91**	**0.80**	**0.84**
Annual Change	N/A	-2.2%	1.5%	-7.0%	5.7%

The Energy, Waste, and Agriculture sectors accounted for over 98% of this province's total GHG emissions in 2003.

A11.3.1 LONG-TERM TRENDS (1990–2003)

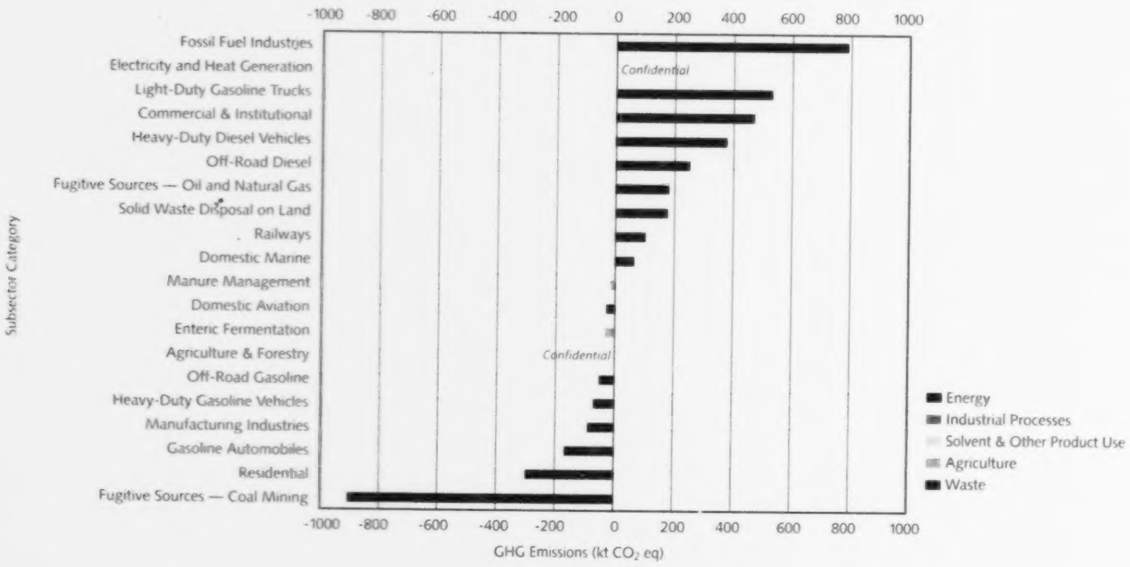
Energy-related emissions increased 10% between 1990 and 2003 and increased 6.8% between 2002 and 2003. In Nova Scotia, the dominant Energy subsectors are electricity and heat generation and road transport. Both subsectors have experienced growth since 1990. LDGVs, LDGTs, and HDDVs dominate transport. The annual contribution from gasoline automobiles has been fairly stable since 1990, while that from LDGTs and HDDTs has shown constant growth over the same period.

Fugitive emissions from coal mining have declined drastically since 1990 (77% less) but are slowly being replaced with those from the oil and gas industry, as the primary energy production source in this province shifts from coal to petroleum (up 27% since 2000).

Total agricultural emissions have been relatively stable in the long term. Emissions from manure management and direct and indirect N_2O emissions from cropland soils increased between 1990 and 2003, while emissions from enteric fermentation declined over this period. Higher poultry populations resulted in higher emissions from manure management, while reductions in both dairy and non-dairy cattle populations reduced emissions from enteric fermentation.

Long-term emission trends in Nova Scotia are illustrated in Figure A11-5.

FIGURE A11-5: **Nova Scotia Long-Term Emission Trends, 1990–2003**

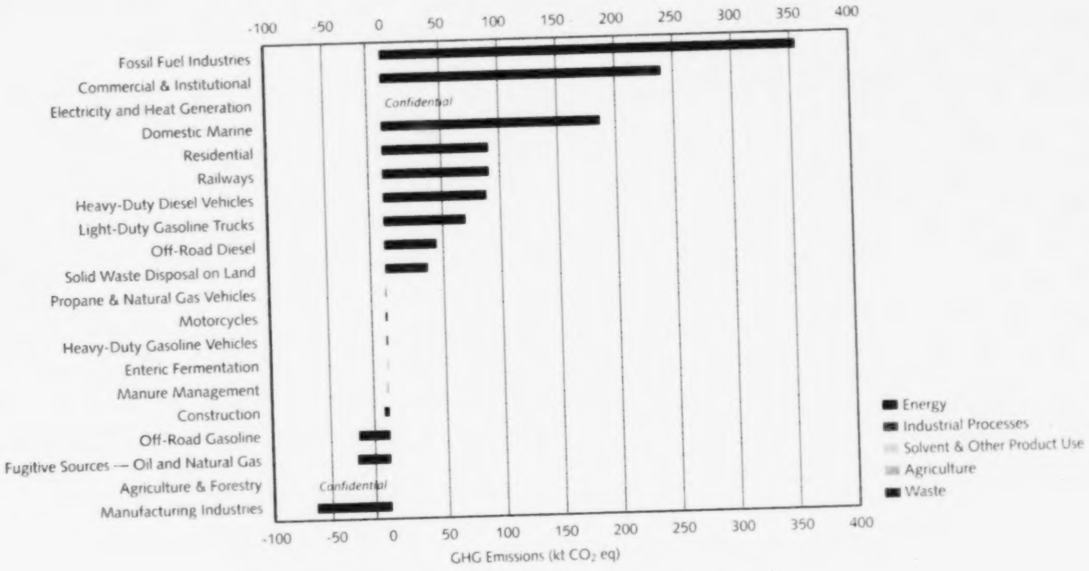


A11.3.2 SHORT-TERM TRENDS (2002–2003)

Between 2002 and 2003, total GHG emissions in Nova Scotia increased by 6.7%, primarily as a result of increased production from the fossil fuel industries. The short-term trend between 2002 and 2003 showed no change in N_2O emissions from manure management and agricultural soils, while CH_4 emissions decreased because of reductions in swine and poultry populations.

Short-term emission trends in Nova Scotia are illustrated in Figure A11-6.

FIGURE A11-6: Nova Scotia Short-Term Emission Trends, 2002–2003



A11.4 NEW BRUNSWICK

In 2003, New Brunswick contributed 21.0 Mt or 2.9% of Canada's total GHG emissions (Table A11-4). This is up 33% since 1990, but down 2.0% since 2002. With 2.4% of Canada's population, New Brunswick's GDP contribution increased 37.5% between 1990 and 2003, representing 1.9% of the national total in 2003. Total HDDs were up 11.9% compared with 1990. In 2003, GHG emissions were 28.0 t per person, up 31% over 1990.

The Energy Sector represents 93% of the provincial GHG total, with the Waste, Agriculture, and Industrial Processes sectors contributing 3.0%, 2.1%, and 2.0%, respectively.

TABLE A11-4: Trends in GHG Emissions and GHG Intensity, New Brunswick

	1990	1995	2000	2002	2003
Total GHG (Mt)	**15.8**	**16.8**	**20.1**	**21.4**	**21.0**
Growth Since 1990	N/A	6.5%	27%	36%	33%
Annual Change	N/A	2.9%	6.6%	-4.5%	-2.0%
GDP Expense – Annual Change	N/A	3.2%	3.1%	4.0%	2.6%
GHG Intensity (Mt/$B GDP)	**1.05**	**1.02**	**1.05**	**1.07**	**1.02**
Annual Change	N/A	-0.4%	3.3%	-8.2%	-4.5%

A11.4.1 LONG-TERM TRENDS (1990–2003)

Emissions growth over the long term (5.2 Mt) was driven by Energy Sector contributions, and emissions have shown almost steady growth from electricity and heat generation (confidential), fossil fuel industries (166%), and transportation (32%). The latter is a result of increases from HDDVs (60%), LDGTs (58%), and off-road use (95%).

Agricultural N_2O emissions from manure management and agricultural soils generally increased between 1990 and 2003, while emissions from enteric fermentation declined over this period. Higher swine and poultry populations resulted in higher CH_4 emissions from manure management. Reductions in both dairy and non-dairy cattle populations reduced emissions from enteric fermentation.

Long-term emission trends in New Brunswick are illustrated in Figure A11-7.

A11.4.2 SHORT-TERM TRENDS (2002–2003)

Similar to the long-term drivers, the short-term reduction in emissions (2%) is primarily attributed to a decrease from electricity and heat generation (confidential) and from fossil fuel industries (7.0%).

The short-term trend also showed a decline in CH_4 emissions from enteric fermentation and manure management because of a reduction in swine and poultry populations. However, emissions of N_2O increased slightly, due mainly to an increase from agricultural soils.

Short-term emission trends in New Brunswick are illustrated in Figure A11-8.

FIGURE A11-7: **New Brunswick Long-Term Emission Trends, 1990–2003**

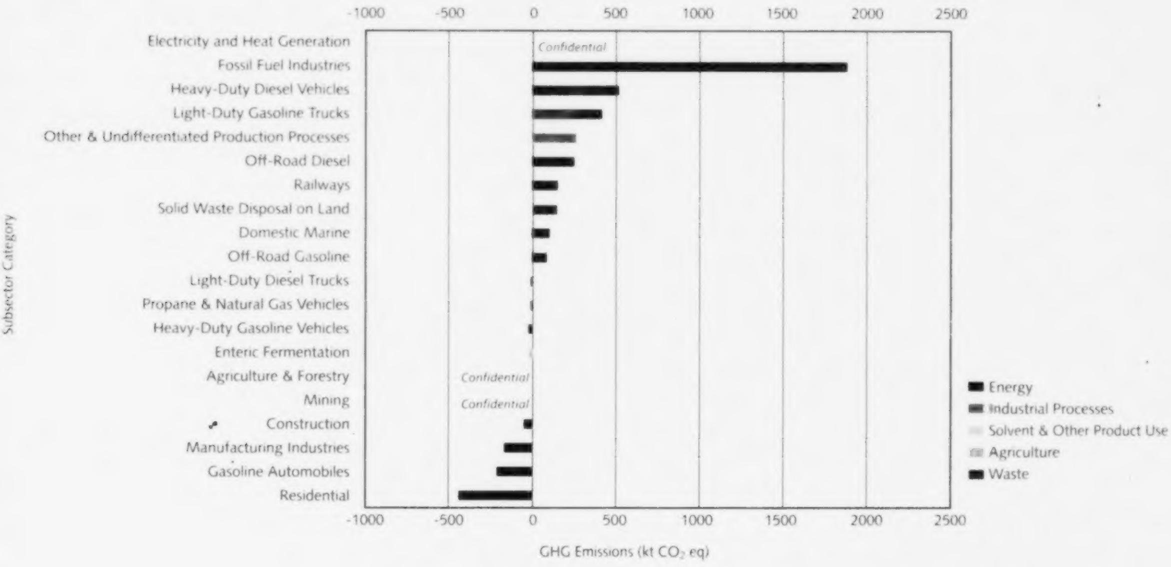
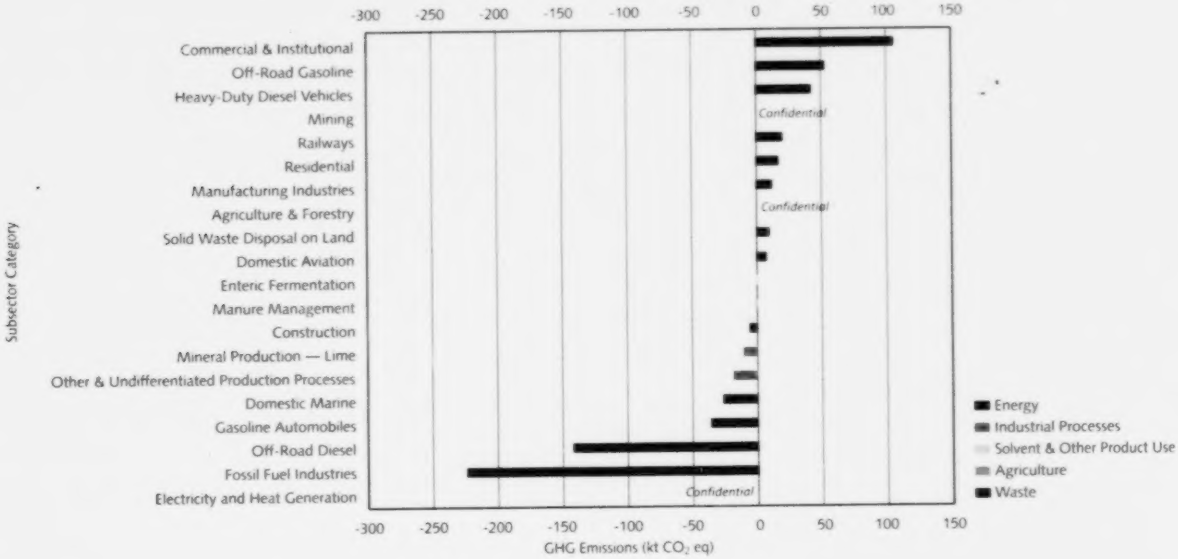


FIGURE A11-8: **New Brunswick Short-Term Emission Trends, 2002–2003**



A11.5 QUEBEC

In 2003, the province of Quebec represented 23.7% (7.5 million) of the country's population and accounted for 21.5% ($232.6 billion) and 13% (91.5 Mt) of Canada's GDP and GHG totals, respectively (Table A11-5). GHG per capita, 12.2 t GHGs per person, and economic GHG intensity, at 0.39 Mt per billion dollars GDP, were both lower than the Canadian average. Since 1990, Quebec's GHG emissions have increased 8.6%, the population has increased 6.9%, and the province's economic output has jumped 36.1%. The year 2003 registered a 10.3% increase in HDDs compared with 1990.

TABLE A11-5: **Trends in GHG Emissions and GHG Intensity, Quebec**

	1990	1995	2000	2002	2003
Total GHG (Mt)	**84.3**	**81.7**	**84.8**	**85.5**	**91.5**
Growth Since 1990	N/A	-3.1%	0.6%	1.4%	8.6%
Annual Change	N/A	-1.1%	0.7%	3.1%	7.1%
GDP Expense – Annual Change	N/A	1.7%	4.7%	4.0%	1.6%
GHG Intensity (Mt/$B GDP)	**0.49**	**0.45**	**0.39**	**0.37**	**0.39**
Annual Change	N/A	-2.7%	-3.8%	-0.9%	5.4%

Because of Quebec's abundant hydro-generated electricity and small petroleum industry, the contribution to total emissions from the Energy Sector is favourable. The Energy, Industrial Processes, Agriculture, and Waste sectors comprise 74%, 11%, 7.8%, and 7.0%, respectively, of the regional total. Transportation and stationary sources contribute 51% and 48%, respectively, to the Energy Sector, while 71% of industrial process emissions are released during aluminium production and magnesium production and casting.

A11.5.1 LONG-TERM TRENDS (1990–2003)

The province of Quebec is by far Canada's primary producer of aluminium and magnesium, with limited activity in Ontario and British Columbia (NRCan). In 2003, Quebec accounted for 83% of Canada's GHG emissions associated with primary aluminium production. The industrial process-related GHG emissions from aluminium production decreased by 15% between 1990 and 2003. The reduction in process emissions can be attributed to better control of anode events in smelters through the use of electronic monitoring and automated emission controls. Although the GDP of the aluminium industry has grown significantly since 1990, its fuel combustion-related

GHG emissions stayed about the same, which indicates efficiency achievements for the industry in regards to its combustion activities. Quebec's magnesium industry emissions declined by 49% between 2002 and 2003, the result of substituting other cover gases for SF_6 in the smelting process, as well as industry rationalizations.

Agricultural N_2O emissions from manure management and agricultural soils remained relatively unchanged between 1990 and 2003. CH_4 emissions from enteric fermentation declined by 12% between 1990 and 2003, mainly due to the reduction in dairy cattle population, while CH_4 emissions from manure management increased by 9% because of the increase in swine population.

Long-term emission trends in Quebec are illustrated in Figure A11-9.

A11.5.2 SHORT-TERM TRENDS (2002–2003)

In the short term, the 7.1% increase in 2003 represents the largest year-to-year change since the inventory has been established. Increases came mainly from the commercial and institutional, electricity and heat generation, and transportation categories. The industrial process-related GHG emissions from aluminium production increased by 1% between 2002 and 2003, while those from Quebec's magnesium industry declined 22% since 2002. A factor contributing to this reduction includes one of two magnesium producers in Quebec ceasing production in April 2003.

The short-term trend between 2002 and 2003 in agricultural emissions showed no changes in CH_4 emissions from enteric fermentation and manure management, while there was a slight increase in N_2O emissions, mainly due to the increase in crop production in 2003.

Short-term emission trends in Quebec are illustrated in Figure A11-10.

FIGURE A11-9: **Quebec Long-Term Emission Trends, 1990–2003**

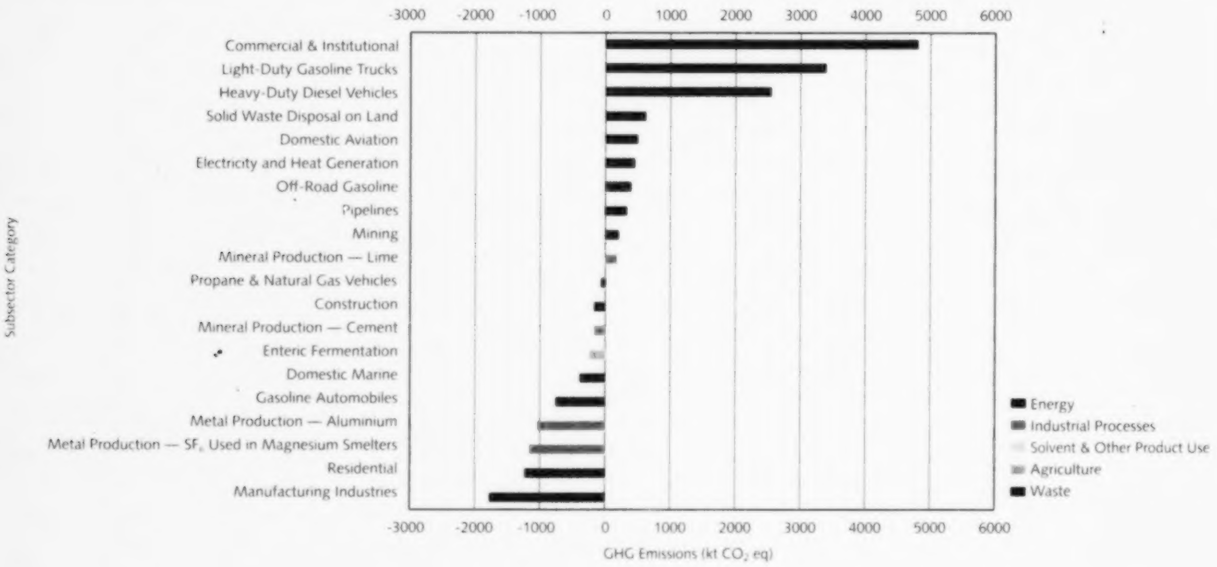
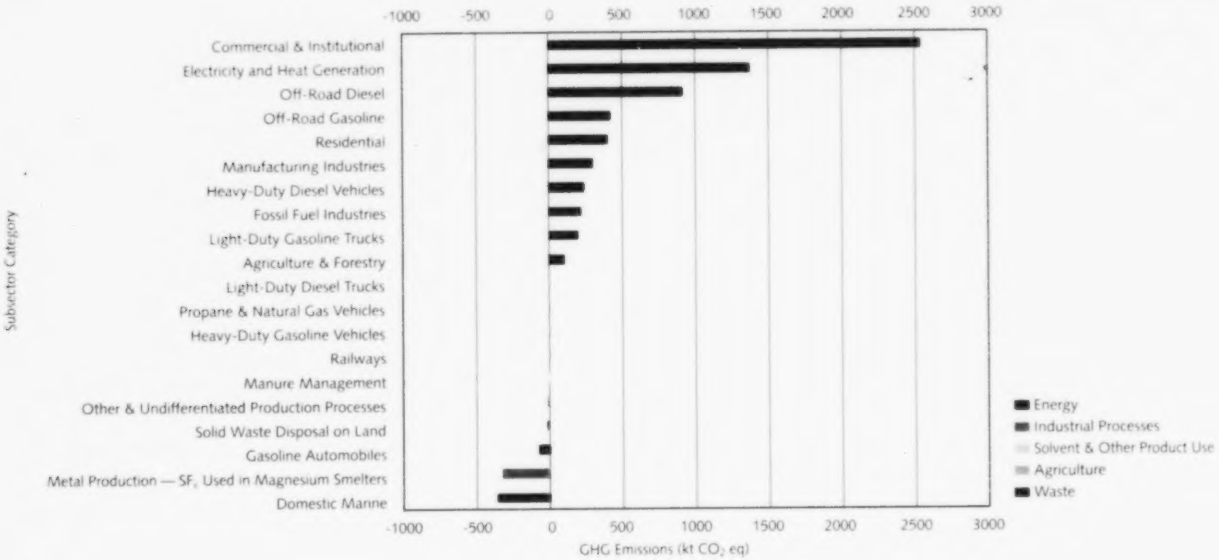


FIGURE A11-10: Quebec Short-Term Emission Trends, 2002–2003



A11.6 ONTARIO

In 2003, Canada's most populated province — at 12.2 million, or 38.7% of the total — generated 28% (206 Mt) of total GHG emissions (Table A11-6) and 42.1% of the country's GDP ($456.8 billion). Between 1990 and 2003, Ontario's emissions increased 27.8 Mt (16%), while GDP and population increased 44.1% and 18.8%, respectively. In the short term (2002–2003), total emission output grew by 1.9% or 3.8 Mt, with a 9.7% increase in HDDs and a 3.3% increase in net supply of primary and secondary energy.

TABLE A11-6: **Trends in GHG Emissions and GHG Intensity, Ontario**

	1990	1995	2000	2002	2003
Total GHG (Mt)	**178.0**	**178.0**	**205.0**	**202.0**	**206.0**
Growth Since 1990	N/A	0.0%	15%	13%	16%
Annual Change	N/A	2.0%	5.0%	3.1%	1.9%
GDP Expense – Annual Change	N/A	3.5%	5.6%	3.6%	1.3%
GHG Intensity (Mt/$B GDP)	**0.56**	**0.52**	**0.48**	**0.45**	**0.45**
Annual Change	N/A	-1.4%	-0.6%	-0.5%	0.6%

Over 90% of Ontario's GHG emissions are attributable to the Energy (82%) and Industrial Processes (8.4%) sectors, with the Agriculture (5.0%) and Waste (4.3%) sectors making up the majority of the remainder.

A11.6.1 LONG-TERM TRENDS (1990–2003)

Between 1990 and 2003, increases in GHG emissions from electricity and heat generation (14.7 Mt), LDGT use (8.9 Mt), HDDVs (6.4 Mt), and commercial and institutional sources (4.9 Mt) were offset by a 90% reduction (9.6 Mt) in the process emissions of the adipic acid industry that resulted from the installation of pollution abatement equipment in 1997. Total electricity generated in Ontario has remained stable since the early 1990s, with coal- and natural gas-fired sources steadily increasing to account for the decline from nuclear sources beginning in the mid-1990s. In Ontario, hydro-generated electricity is still second to nuclear, although coal is now a close third.

In the Agriculture Sector, CH_4 emissions from enteric fermentation decreased by 8% between 1990 and 2003, due mainly to the reduction in dairy cattle population. Net growth in CH_4 emissions from manure management was the result of an increase in swine population being offset by a decrease in dairy cattle population between 1990 and 2003, while N_2O emissions from manure management and agricultural soils remained relatively unchanged over the same period.

Long-term emission trends in Ontario are illustrated in Figure A11-11.

A11.6.2 SHORT-TERM TRENDS (2002–2003)

The majority of the short-term reductions are realized in the Energy Sector, specifically in the pipelines, off-road diesel, railways, chemical manufacturing, and fossil fuel production subsectors. The short-term emissions growth is led by those attributable to the residential subsector (1.8 Mt), the commercial and institutional subsector (1.1 Mt), HDDVs (0.9 Mt), and electricity and heat generation (0.8 Mt).

The short-term trend in Agriculture showed a reduction in N_2O emissions, mainly due to the decrease in nitrogen fertilizer consumption in 2003. There was an increase in CH_4 emissions from enteric fermentation associated with an increase in the population of non-dairy cattle during 2003.

Short-term emission trends in Ontario are illustrated in Figure A11-12.

FIGURE A11-11: **Ontario Long-Term Emission Trends, 1990–2003**

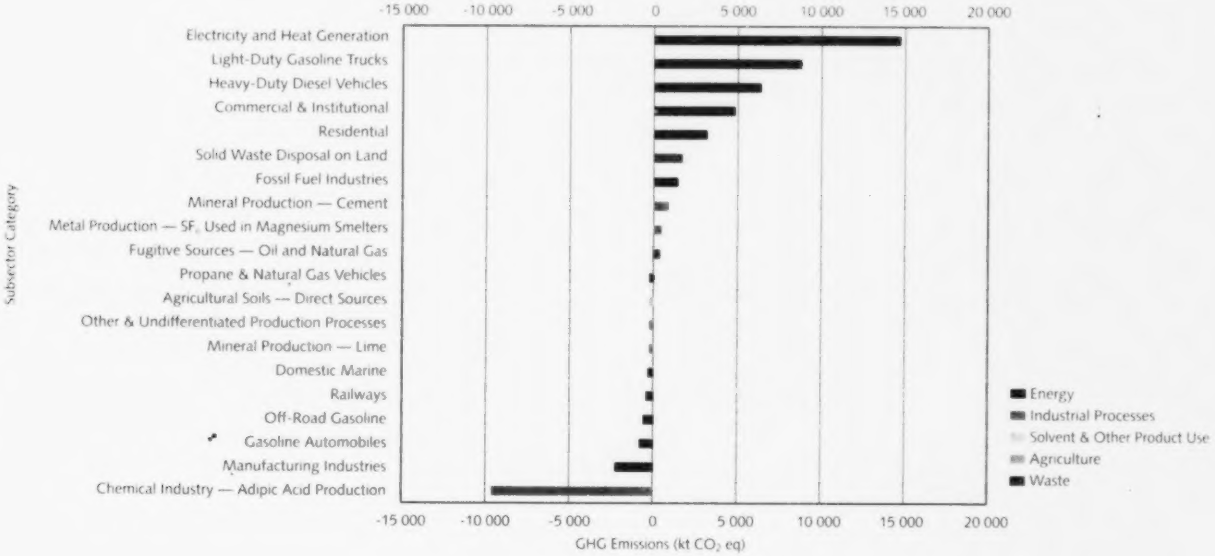
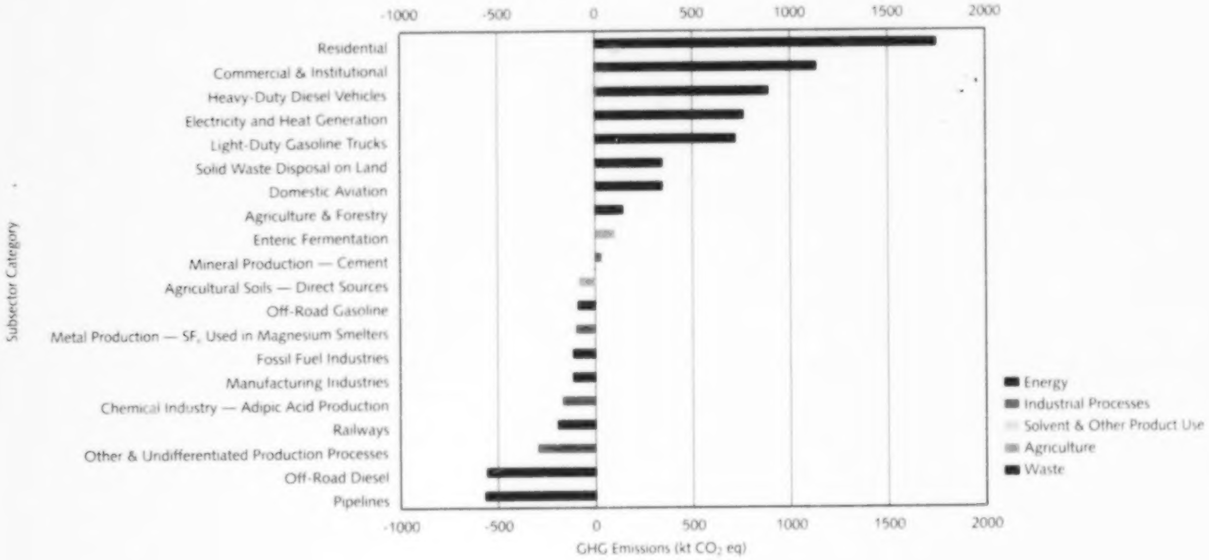


FIGURE A11-12: Ontario Short-Term Emission Trends, 2002–2003



A11.7 MANITOBA

In 2003, Manitoba's GHG emissions were up 12% (2.3 Mt) with respect to 1990's total of 19.1 Mt and up 3.0% (0.6 Mt) since 2002 (Table A11-7). Over the long term, the province's annual GDP and population increased 26.7% and 5.2%, respectively, contributing 18.4 t of GHGs per person and 618 kt GHGs per billion dollars GDP in 2003.

TABLE A11-7: Trends in GHG Emissions and GHG Intensity, Manitoba

	1990	1995	2000	2002	2003
Total GHG (Mt)	**19.1**	**20.4**	**21.5**	**20.7**	**21.3**
Growth Since 1990	N/A	7.0%	13%	8.6%	12%
Annual Change	N/A	4.3%	3.1%	3.8%	3.0%
GDP Expense – Annual Change	N/A	0.3%	4.6%	2.1%	1.4%
GHG Intensity (Mt/$B GDP)	**0.70**	**0.73**	**0.65**	**0.61**	**0.62**
Annual Change	N/A	4.0%	-1.4%	1.7%	1.5%

A11.7.1 LONG-TERM TRENDS (1990–2003)

Manitoba's economic structure gives its GHG inventory the lowest percentage of emissions from the Energy Sector (59%) and the highest percentage from the Agriculture Sector (37%). The overall contributions from the Energy Sector have been fairly stable over the long term, with increases from LDGTs (0.7 Mt) and HDDVs (0.5 Mt) being offset by reductions from LDGVs (0.5 Mt), railways (0.4 Mt), pipelines (0.4 Mt), and residential (0.4 Mt) subsectors.

Agricultural emissions from all sources increased significantly between 1990 and 2003. CH_4 emissions from enteric fermentation and manure management increased by 49%, mainly due to increases in non-dairy cattle and swine populations. N_2O emissions from manure management and agricultural soils increased by 32%, mainly due to increases in nitrogen fertilizer consumption, animal manure on pasture, and animal manure applied as fertilizers on cropland.

Long-term emission trends in Manitoba are illustrated in Figure A11-13.

A11.7.2 SHORT-TERM TRENDS (2002–2003)

Short-term increases in N_2O emissions from agricultural soils between 2002 and 2003 resulted from increased fertilizer nitrogen consumption and higher crop production in 2003. CH_4 emissions also increased in 2003 because of higher beef cattle population.

Short-term emission trends in Manitoba are illustrated in Figure A11-14.

FIGURE A11-13: Manitoba Long-Term Emission Trends, 1990–2003

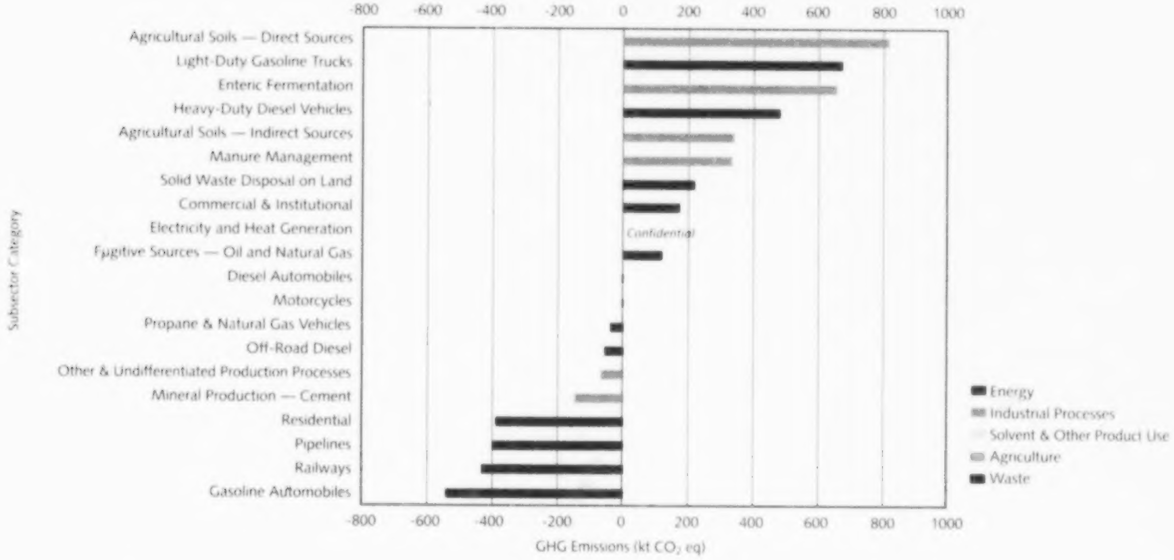
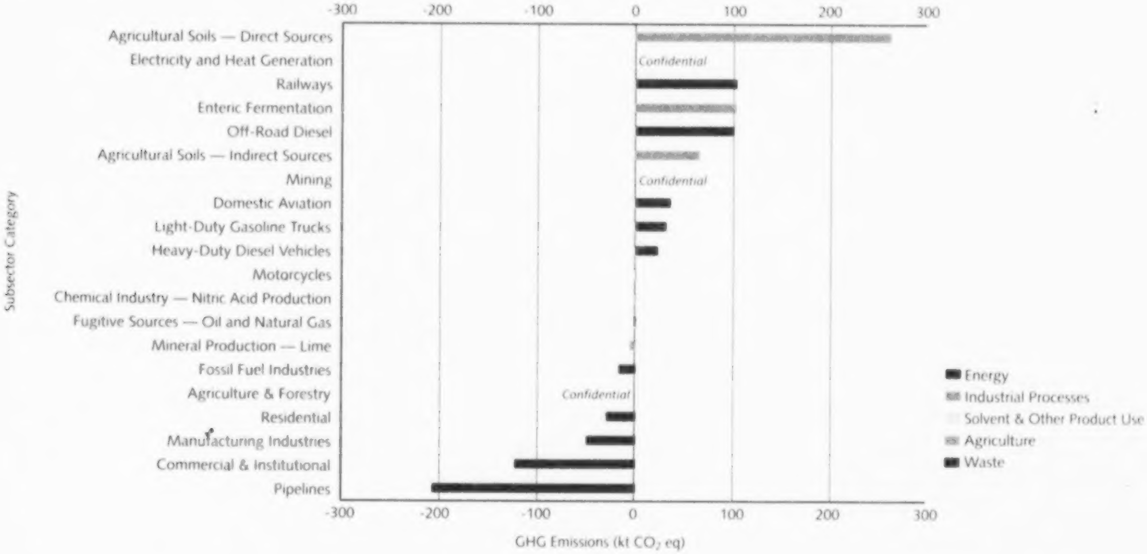


FIGURE A11-14: Manitoba Short-Term Emission Trends, 2002–2003



A11.8 SASKATCHEWAN

Saskatchewan generated 65.2 Mt GHGs in 2003 (8.9% of Canada's total), a 45% increase over the 1990 base year and a 4.3% increase compared with 2002 (Table A11-8). GDP output increased 28.9% between 1990 and 2003, while population declined by 1.2%. In 2003, these measures translated to over 66 t GHGs per person and 20 230 kt GHGs per billion dollars GDP.

TABLE A11-8: **Trends in GHG Emissions and GHG Intensity, Saskatchewan**

	1990	1995	2000	2002	2003
Total GHG (Mt)	**45.0**	**59.4**	**64.2**	**62.5**	**65.2**
Growth Since 1990	N/A	32%	42%	39%	45%
Annual Change	N/A	4.1%	1.0%	0.0%	4.3%
GDP Expense – Annual Change	N/A	1.1%	3.2%	-1.5%	4.5%
GHG Intensity (Mt/$B GDP)	**1.81**	**2.18**	**2.04**	**2.03**	**2.03**
Annual Change	N/A	3.0%	-2.2%	1.5%	-0.2%

Saskatchewan's emission contribution per sector represents the natural westerly transition across Canada's central provinces — that is, an increasing portion of energy-related emissions, accounting for 75% of the province's emission sources.

A11.8.1 LONG-TERM TRENDS (1990–2003)

Long-term growth trends show Energy subsectors as strong contributors, specifically emissions from electricity and heat generation and the petroleum industries, including combustion emissions from the fossil fuel industries and fugitive emissions from oil and natural gas. Total electricity produced showed steady growth since 1990. Coal-generated capacity has remained the predominant source of electricity and appears to have peaked, while the demand for electricity from natural gas sources continues to increase strongly.

Primary energy production increased 52% between 1990 and 2003, while net supply and energy use – final demand increased 28.1% and 22.0%, respectively. The annual HDDs measured in 2003 declined 0.3% compared with 1990 and 1.2% compared with 2002.

Agricultural emissions from enteric fermentation, manure management, and agricultural soils grew substantially between 1990 and 2003. CH_4 emissions from enteric fermentation and manure management increased by 46%, due mainly to increases in beef cattle and swine populations. N_2O emissions from manure management and agricultural soils increased by 53%, due mainly to increases in fertilizer nitrogen consumption and pulse crop production.

Long-term emission trends in Saskatchewan are illustrated in Figure A11-15.

A11.8.2 SHORT-TERM TRENDS (2002–2003)

The short-term trend in agricultural emissions between 2002 and 2003 followed the same pattern as described for the long term, with the exception of direct N_2O emissions from cropland soils. Here, emissions decreased in 2002, because of poorer production of both legume and non-legume crops and lower use of synthetic fertilizer.

Short-term emission trends in Saskatchewan are illustrated in Figure A11-16.

FIGURE A11-15: **Saskatchewan Long-Term Emission Trends, 1990–2003**

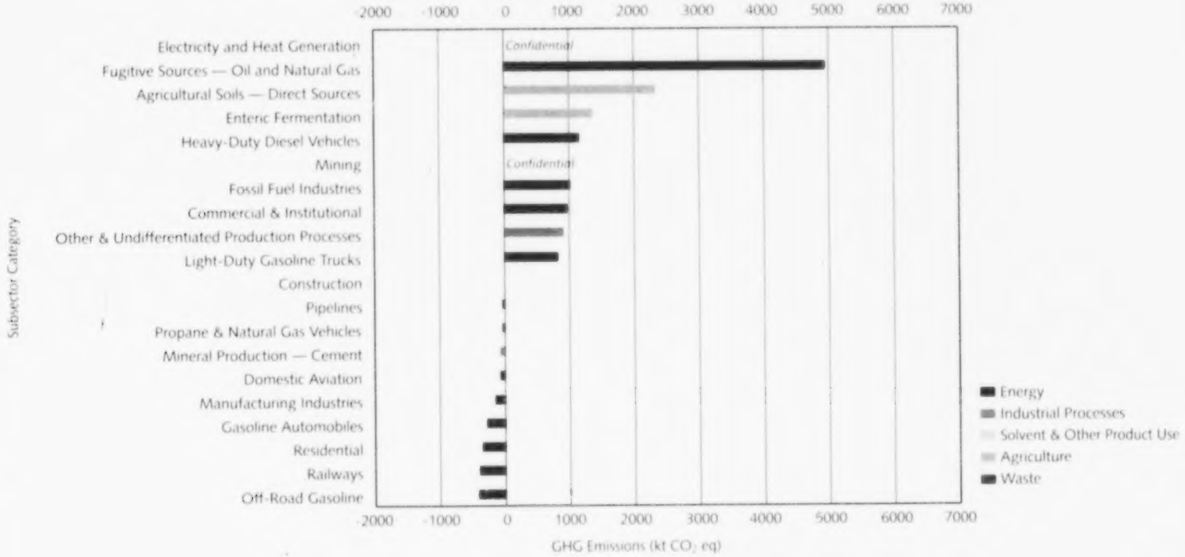
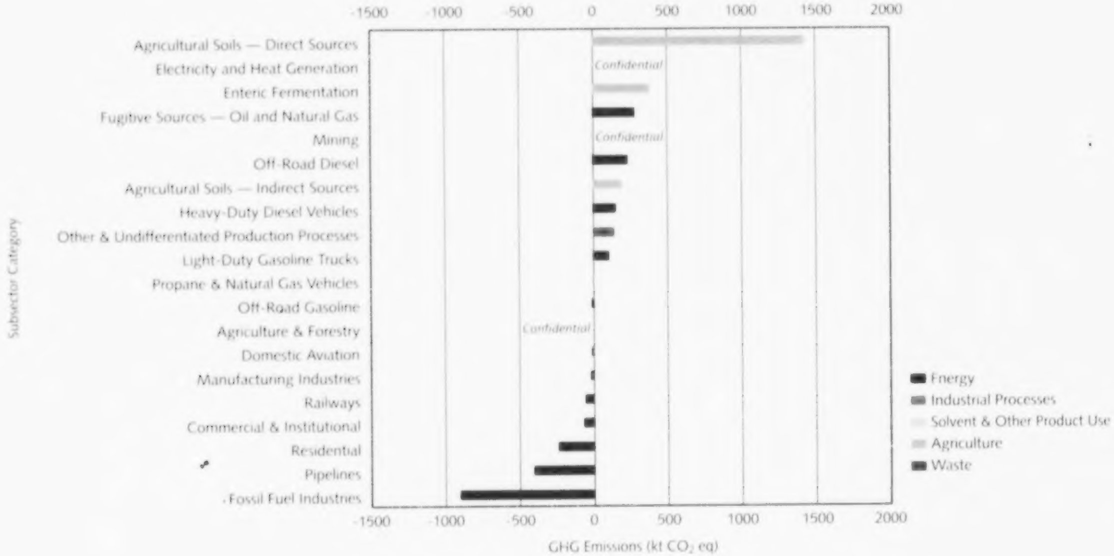


FIGURE A11-16: **Saskatchewan Short-Term Emission Trends, 2002–2003**



A11.9 ALBERTA

The province of Alberta generated 12% of Canada's GDP in 2003, with 10.0% of the total population. Between 1990 and 2003, GDP and GHG output increased 55.7% and 34% to $128.5 billion and 224 Mt, respectively (Table A11-9). The short-term trends show a 2.7% growth in total GHG emissions, while observing a 2.2% increase in economic output and a 3.6% increase in HDDs since the previous year.

TABLE A11-9: **Trends in GHG Emissions and GHG Intensity, Alberta**

	1990	1995	2000	2002	2003
Total GHG (Mt)	**168**	**197**	**221**	**218**	**224**
Growth Since 1990	N/A	17%	32%	30%	34%
Annual Change	N/A	2.5%	3.9%	-0.1%	2.7%
GDP Expense – Annual Change	N/A	3.1%	5.7%	1.5%	2.2%
GHG Intensity (Mt/$B GDP)	**2.03**	**2.00**	**1.83**	**1.74**	**1.75**
Annual Change	N/A	-0.6%	-1.7%	-1.5%	0.6%

Alberta, known for its abundant fossil fuel-based natural resources, provided 64% of Canada's primary energy production in 2003. Not surprisingly, the province's total GHG emissions are dominated by combustion emissions related to the IPCC Energy Sector. With 87% of the provincial total from the Energy Sector, the remaining sources are a combination of the Agriculture (8.3%) and Industrial Processes (3.8%) sectors.

A11.9.1 LONG-TERM TRENDS (1990–2003)

Long-term emissions growth has contributed an additional 56.8 Mt to the provincial total, predominantly driven by increases from electricity and heat generation (14.7 Mt), fossil fuel industries (13 Mt), mining (8.6 Mt), fugitive sources from the oil and gas industry (7.3 Mt), HDDVs (3.8 Mt), LDGTs (2.5 Mt), and pipelines (1.8 Mt), all of which are constituents of the Energy Sector. Decreases over the long term have been limited to combustion emissions from manufacturing industries (1.6 Mt) and LDGVs (1.0 Mt).

Agricultural emissions from enteric fermentation, manure management, and agricultural soils grew substantially between 1990 and 2003. CH_4 emissions from enteric fermentation and manure management increased by 33%, while N_2O emissions from manure management and agricultural soils increased by 18%. The main factors contributing to the increased emissions were higher beef cattle and swine populations and greater use of synthetic nitrogen fertilizers.

Long-term emission trends in Alberta are illustrated in Figure A11-17.

A11.9.2 SHORT-TERM TRENDS (2002–2003)

The one-year growth of 2.7% was the result of increases in mining (3.5 Mt), electricity and heat generation (1.9 Mt), and HDDVs (0.7 Mt), offset by either no change or reductions in subsectors that had historically been responsible for high growth, such as fossil fuel industries, fugitive sources from oil and natural gas, and pipelines. Driving this trend was the fact that fossil fuel production and sales in 2003 showed very little net growth, and, compared with 2002, natural gas exports fell. It is unclear what implications this one-year change has for the longer term.

Agricultural short-term trends show a reduction in emissions of N_2O and CH_4 from enteric fermentation and manure management as a result of reduction in non-dairy cattle, dairy cattle, swine, and poultry populations in 2003. There was an increase in N_2O emissions from crop production, as a result of better legume and non-leguminous crop production in 2003.

Short-term emission trends in Alberta are illustrated in Figure A11-18.

FIGURE A11-17: Alberta Long-Term Emission Trends, 1990–2003

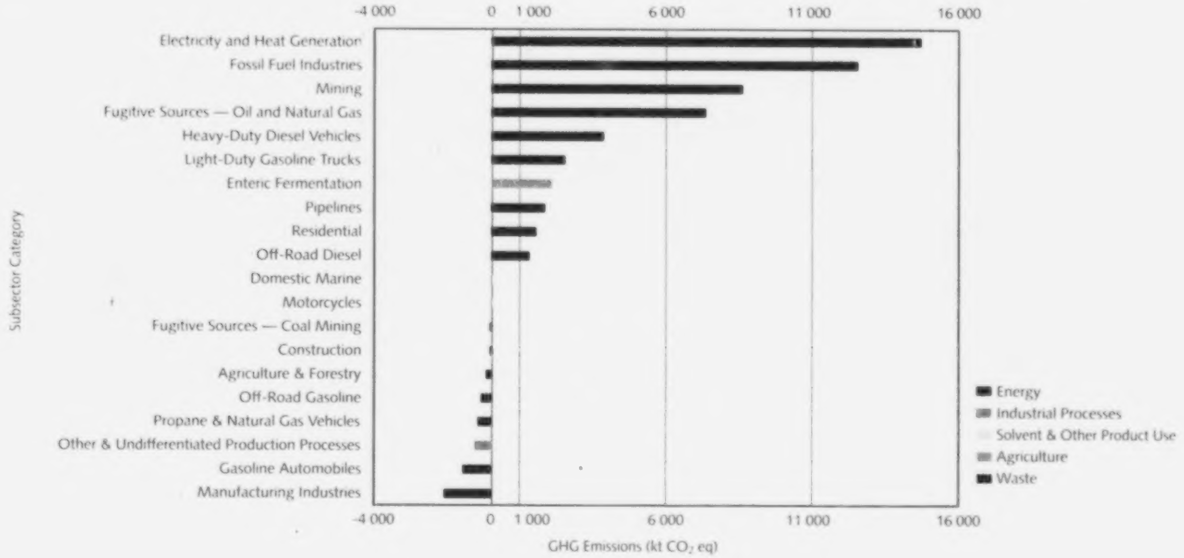
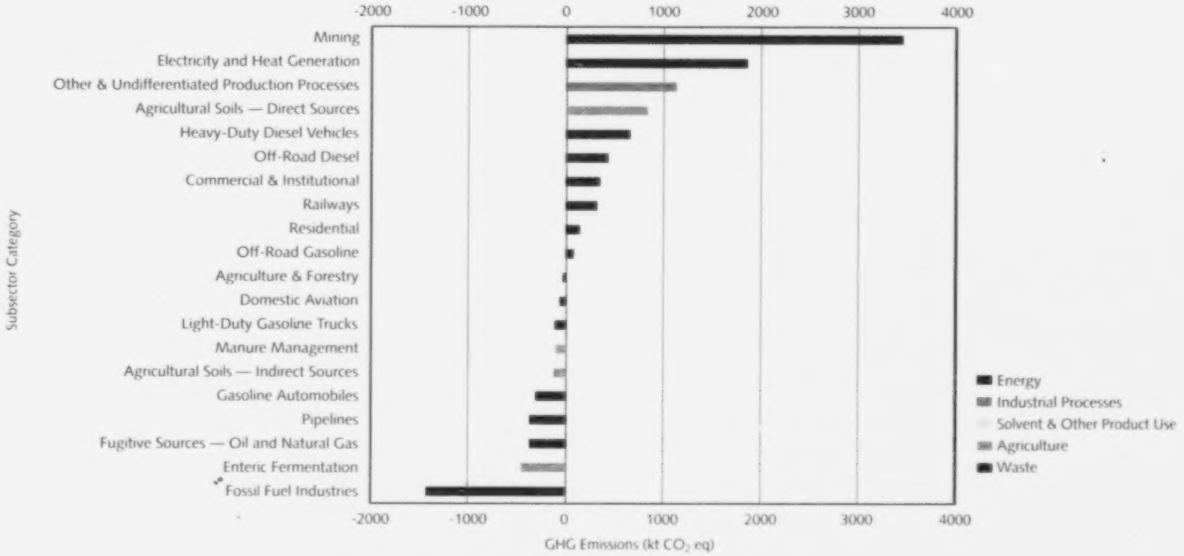


FIGURE A11-18: Alberta Short-Term Emission Trends, 2002–2003



A11.10 BRITISH COLUMBIA

In 2003, British Columbia's 4.1 million residents generated 63.4 Mt of total GHGs (Table A11-10) and contributed $130.9 billion to the country's GDP. This represents 8.7% of Canada's total GHG emissions and 12.1% of the total GDP. Between 1990 and 2003, the province's total emissions increased 12.1 Mt or 24%, while GDP and population increased 36.8% and 26.0%, respectively. British Columbia's annual generation rate increased to 15.3 t GHGs per person since 1990, and its GHG per GDP works out to 484 kt per billion dollars in 2003. In the short term (2002–2003), total emission output increased 1.2 Mt or 2.0%. The province's annual HDDs decreased by 8.7% between 1990 and 2003 and by 6.8% since 2002.

TABLE A11-10: **Trends in GHG Emissions and GHG Intensity, British Columbia**

	1990	1995	2000	2002	2003
Total GHG (Mt)	**51.3**	**59.6**	**64.3**	**62.2**	**63.4**
Growth Since 1990	N/A	16%	25%	21%	24%
Annual Change	N/A	8.2%	2.8%	-2.0%	2.0%
GDP Expense – Annual Change	N/A	2.4%	4.8%	2.4%	2.2%
GHG Intensity (Mt/$B GDP)	**0.54**	**0.55**	**0.51**	**0.49**	**0.48**
Annual Change	N/A	5.7%	-1.9%	-4.2%	-0.2%

A review of B.C.'s sectors shows 83% of GHG emissions arising from the Energy Sector. The Waste, Agriculture, and Industrial Processes sectors add 8.5%, 4.0%, and 4.3%, respectively. Within the Energy Sector, stationary sources represent 38%, transportation sources represent 48%, and fugitive emissions make up the remaining 13%, predominantly from oil and natural gas operations.

A11.10.1 LONG-TERM TRENDS (1990–2003)

This province's Energy Sector and its subsectors contributed the greatest to changes in annual GHGs in the long term. Eight of the top 10 long-term growth subsectors are in the Energy Sector, and four of those are represented by transportation, a subsector that has registered over 35% growth since 1990. Increases from LDGTs, HDDVs, and domestic aviation have been offset by reductions from gasoline automobiles, alternatively fuelled vehicles, and railways. Fugitive emissions from oil and natural gas increased 3.5 Mt or 117% between 1990 and 2003, while combustion emissions from the fossil fuel industries increased 21%. B.C.'s production of primary energy increased 34.9% between 1990 and 2003, while its net supply increased only 15.8%.

CH_4 emissions from enteric fermentation increased by 18% from 1990 to 2003, mainly due to the increase in beef cattle population. N_2O emissions from manure management increased, but this increase was offset by a similar decrease from agricultural soils over the same period. The decreases in N_2O emissions were due to the reductions in synthetic fertilizer nitrogen consumption and the swine population, and the increase in N_2O emissions was due to the increase in the poultry population.

Long-term emission trends in British Columbia are illustrated in Figure A11-19.

A11.10.2 SHORT-TERM TRENDS (2002–2003)

In the short term, 7 of the top 10 growth subsectors belong to the Energy Sector, led by an almost 60% increase in emissions from domestic marine followed by a 25% increase in those from fossil fuel industries. The Waste Sector sources have increased a total of over 48% since 1990, but 1.8% since 2002. British Columbia's portion of emissions from the Waste Sector (8.5%) surpasses those of the remaining provinces/territories, with 94% of this sector's total coming from solid waste disposal on land. Much of this is the result of the landfilling of wood waste by B.C.'s large forest industry.

The short-term trend showed increases in both N_2O and CH_4 emissions between 2002 and 2003. CH_4 emissions from enteric fermentation increased because of an increase in the beef cattle population, and N_2O emissions from agricultural soils and manure management also increased because of increases in the beef cattle population and synthetic fertilizer nitrogen consumption in 2003.

Short-term emission trends in British Columbia are illustrated in Figure A11-20.

FIGURE A11-19: **British Columbia Long-Term Emission Trends, 1990–2003**

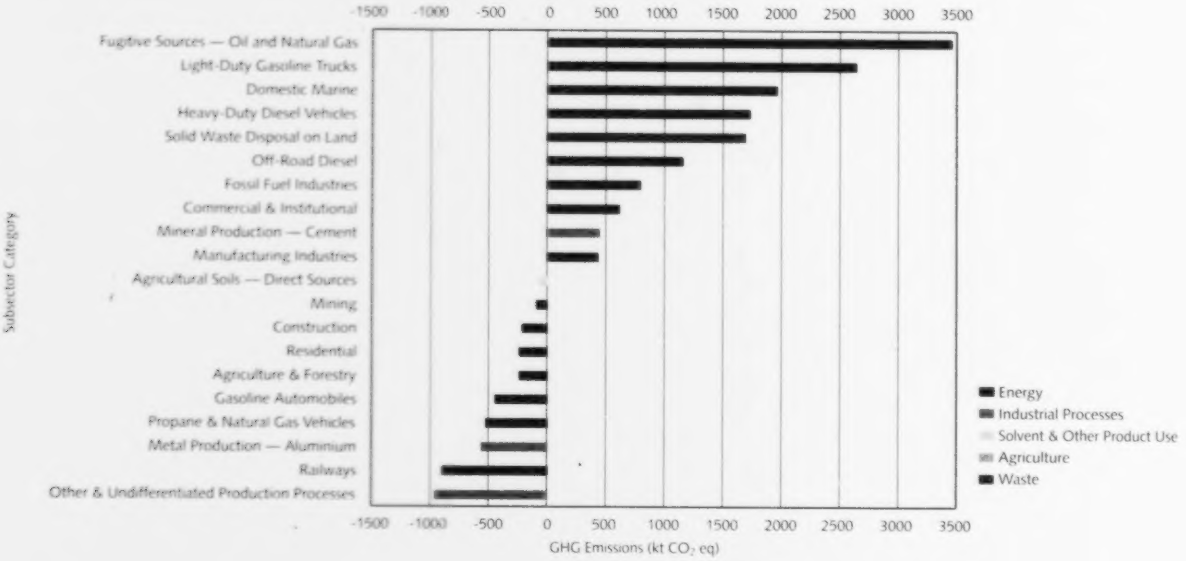
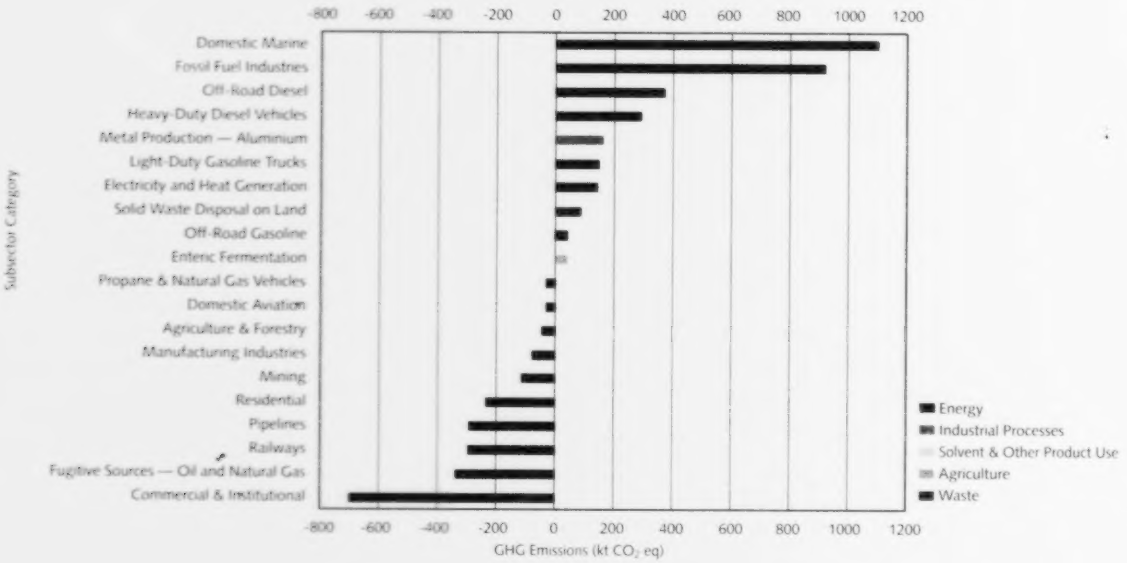


FIGURE A11-20: **British Columbia Short-Term Emission Trends, 2002–2003**



A11.11 YUKON, NORTHWEST TERRITORIES, AND NUNAVUT

Together, Canada's territories contributed 2.2 Mt (Table A11-11) or 0.2% to the national GHG total and $4.1 billion or 0.4% to the national GDP in 2003. Ninety-eight percent of the territories' total emissions are from the Energy Sector.

TABLE A11-11: Trends in GHG Emissions and GHG Intensity, Total Territories

	1990	1995	2000	2002	2003
Total GHG (Mt)	**2.04**	**2.47**	**2.22**	**2.39**	**2.23**
Growth Since 1990	N/A	21%	8.4%	16%	8.8%
Annual Change	N/A	7.2%	14%	-14%	-6.6%
GDP Expense – Annual Change	N/A	3.4%	5.1%	2.9%	4.5%
GHG Intensity (Mt/$B GDP)	**0.59**	**0.69**	**0.52**	**0.47**	**0.42**
Annual Change	N/A	3.6%	8.6%	-17%	-11%

Yukon, with a GHG emissions total for 2003 just under 0.5 Mt (Table A11-12), has shown an 8.5% reduction since 1990, most of which is due to reductions in combustion emissions from the off-road and electricity and heat generation subsectors. Although total emissions went down, there was an increase from the petroleum industry, including both combustion emissions from the fossil fuel industries and fugitive emissions from oil and natural gas operations. These two subsectors have shown growth since the early 1990s, and the modest long-term trend has only recently been mitigated by an abrupt and substantial short-term decrease. Since 1990, Yukon's population has increased almost 21%, while its GDP has increased over 14%. Per capita, Yukon residents are each attributed 6.6 t GHGs annually, very low compared with the Canadian average and down over 24% since 1990, due to the increased population.

TABLE A11-12: Trends in GHG Emissions and GHG Intensity, Yukon

	1990	1995	2000	2002	2003
Total GHG (Mt)	**0.514**	**0.658**	**0.518**	**0.485**	**0.470**
Growth Since 1990	N/A	28%	0.9%	-5.6%	-8.5%
Annual Change	N/A	11%	-8.4%	0.7%	-3.1%
GDP Expense – Annual Change	N/A	16.4%	6.5%	0.2%	0.2%
GHG Intensity (Mt/$B GDP)	**0.50**	**0.62**	**0.45**	**0.42**	**0.40**
Annual Change	N/A	-4.9%	-14%	0.5%	-3.2%

The Northwest Territories and Nunavut generated around 1.8 Mt total GHGs in 2003 (Table A11-13). This is a 15% increase since 1990, which has been driven almost entirely by increases within the Energy Sector. Annual growth in emissions, predominantly in the off-road subsector, but including fugitive oil and gas, mining, and electricity and heat generation subsectors, has been sustained throughout the long term. Since 1990, the combined population of these regions has increased 12% to over 31 000, during which time the annual GDP has grown almost 67%. GHG emissions per capita registered almost 57 t in 2003, a 2.5% decrease over 1990.

As a whole, HDDs for the three territories for 2003 show an overall decrease of around 8% compared with 1990 and 1% less than in 2002. Energy production (primary only) expanded 14% from 1990, while net supply and energy use – final demand rose 5% and 8%, respectively.

Long-term emission trends in Yukon and in the Northwest Territories and Nunavut are illustrated in Figures A11-21 and A11-22, respectively. Short-term emission trends in Yukon and in the Northwest Territories and Nunavut are illustrated in Figures A11-23 and A11-24, respectively.

TABLE A11-13: Trends in GHG Emissions and GHG Intensity, Northwest Territories and Nunavut

	1990	1995	2000	2002	2003
Total GHG (Mt)	**1.53**	**1.81**	**1.70**	**1.90**	**1.76**
Growth Since 1990	N/A	18%	11%	24%	15%
Annual Change	N/A	5.9%	23%	-17%	-7.4%
GDP Expense – Annual Change	N/A	-1.3%	4.6%	3.8%	5.8%
GHG Intensity (Mt/$B GDP)	**0.62**	**0.73**	**0.54**	**0.49**	**0.43**
Annual Change	N/A	7.3%	18%	-21%	-13%

FIGURE A11-21: Yukon Long-Term Emission Trends, 1990–2003

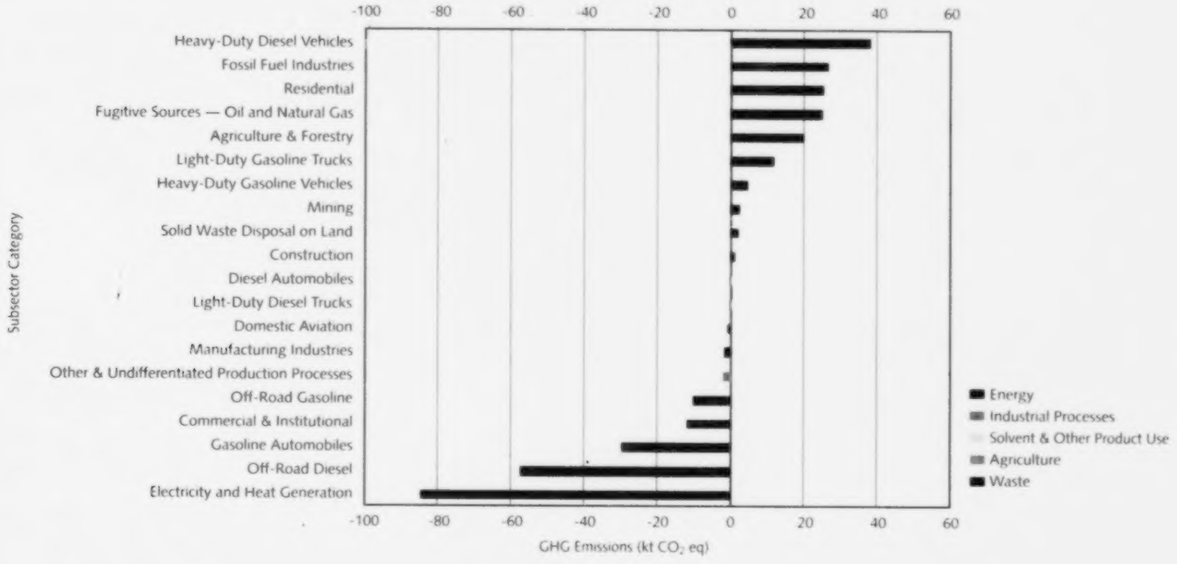


FIGURE A11-22: Northwest Territories and Nunavut Long-Term Emission Trends, 1990–2003

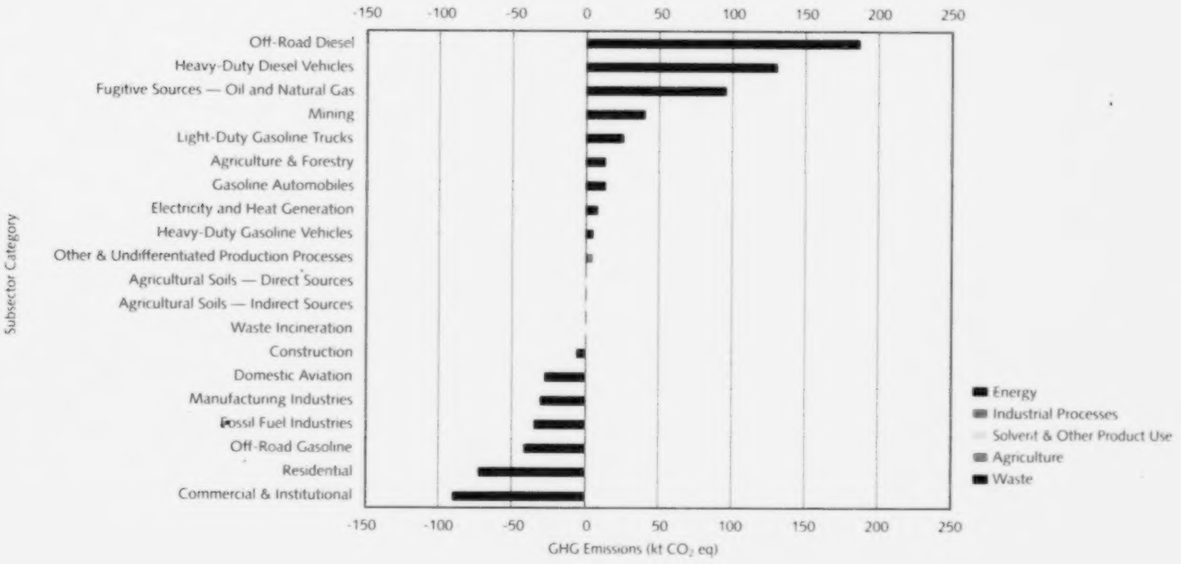


FIGURE A11-23: Yukon Short-Term Emission Trends, 2002–2003

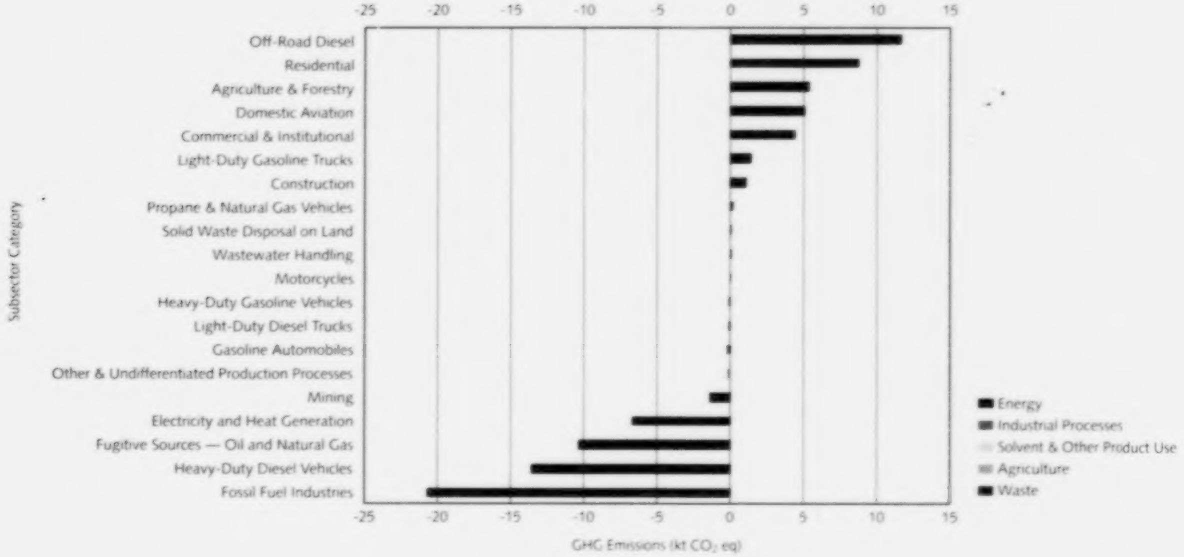
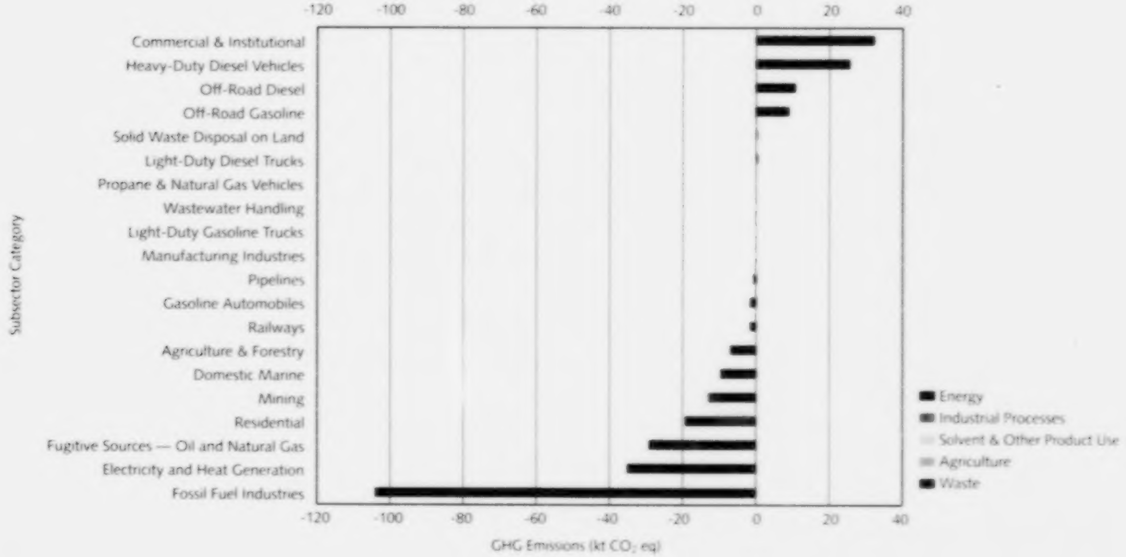


FIGURE A11-24: Northwest Territories and Nunavut Short-Term Emission Trends, 2002–2003



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ANNEX 12: PROVINCIAL/TERRITORIAL GREENHOUSE GAS EMISSION TRENDS, 1990–2003

Summary tables illustrating GHG emissions by province/territory, sector, and year are included in Annex 12. Although the UNFCCC Reporting Guidelines require that only national-level detail be reported, provincial- and territorial-level detail is important due to the regional differences in emission levels and trends. Note that provincial and territorial emission estimates may not necessarily sum to the national totals due to rounding and suppression of confidential data. Provincial and territorial emission totals do not include:

1) HFCs (e.g., fugitive releases from AC and refrigeration systems);
2) PFCs (used during the fabrication of semi-conductors);
3) CO_2 from limestone and soda ash use; and
4) emissions associated with ammonia production.

TABLE A12-1: Greenhouse Gas Category Description

GHG Source/Sink Categories	
ENERGY	
a. **Stationary Combustion Sources**	
Electricity and Heat Generation	Emissions from fuel consumed by:
Electricity Generation	Utility and industry electricity generation
Heat Generation	Steam generation (for sale)
Fossil Fuel Industries	Emissions from fuel consumed by:
Petroleum Refining	Petroleum refining industries (including upstream facilities)
Fossil Fuel Production	Conventional and unconventional oil and gas production industries (some refining is included)
Mining	Emissions from commercial fuel sold to: Metal and non-metal mines, stone quarries, and gravel pits Oil and gas extraction industries Mineral exploration and contract drilling operation
Manufacturing Industries	Emissions from fuel consumed by the following industries: Iron and Steel (steel foundries, casting and rolling mills) Non-Ferrous metals (aluminium, magnesium, and other production) Chemical (fertilizer manufacturing, organic and inorganic chemical manufacturing) Pulp and paper (primarily pulp, paper and paper product manufacturers) Cement production Other manufacturing industries not listed (such as automobile manufacturing, textiles, food and beverage industries)
Construction	Emissions from fuels consumed by the construction industry – buildings, highways, etc.
Commercial & Institutional	Emissions from fuel consumed by: Service industries related to mining, communication, wholesale and retail trade, finance and insurance, real estate, education, etc. Federal, provincial, and municipal establishments National Defence and Canadian Coast Guard Train stations, airports, and warehouses
Residential	Emissions from fuels consumed for personal residences (homes, apartment hotels, condominiums, and farms)
Agriculture & Forestry	Emissions from fuel consumed by: Forestry and logging service industry Agriculture, hunting and trapping industry (excluding food processing, farm machinery manufacturing and repair)
b. **Transportation**	Emissions resulting from the combustion and/or fugitive releases due to moving passengers, freight, and commodities throughout Canada
Domestic Aviation	Emissions resulting from the consumption of fossil fuels by Canadian-registered airlines flying domestically
Road Transportation	Emissions resulting from the consumption of fossil fuels by vehicles licensed to operate on roads
Railways	Emissions resulting from the consumption of fossil fuels by Canadian railways
Domestic Marine	Emissions resulting from the consumption of fossil fuels by Canadian-registered marine vessels fuelled domestically
Others - Off-Road	Emissions resulting from the consumption of fossil fuels by combustion devices not licensed to operate on roads
Others - Pipelines	Emissions resulting from the transportation and distribution of crude oil, natural gas, and other products
c. **Fugitive Sources**	Intentional and unintentional releases of GHGs from the following activities:
Coal Mining	Underground and surface mining
Oil and Natural Gas	Conventional and unconventional oil and gas exploration, production, transportation, and distribution
INDUSTRIAL PROCESSES	Emissions resulting from the following process activities:
a. **Mineral Production**	Production of cement and lime; use of soda ash and limestone
b. **Chemical Industry**	Production of ammonia, nitric acid, and adipic acid
c. **Metal Production**	Production of aluminium, iron and steel; magnesium production and casting
d. **Consumption of Halocarbons and SF_6**	Use of HFCs and/or PFCs in air conditioning units, refrigeration units, fire extinguishers, aerosol cans, solvents, foam blowing, semi-conductor manufacturing and electronics industry, use of SF_6 in electrical equipment
e. **Other & Undifferentiated Production**	Non-energy use of fossil fuels
SOLVENT & OTHER PRODUCT USE	Emissions resulting from the use of N_2O as anaesthetic and propellant
AGRICULTURE	Emissions resulting from:
a. **Enteric Fermentation**	Livestock
b. **Manure Management**	Livestock waste management
c. **Agricultural Soils**	Direct and indirect emissions from mineral soils, histosols, atmospheric deposition, and runoff
Direct Sources	Emissions resulting from synthetic fertilizer, manure N on pasture and cropland, biological N fixation, crop residue, and cultivation of organic soils
Indirect Sources	Emissions from animal manure nitrogen and synthetic fertilizer nitrogen
WASTE	Emissions resulting from:
a. **Solid Waste Disposal on Land**	Municipal waste management sites (landfills) and wood waste landfills
b. **Wastewater Handling**	Domestic wastewater treatments
c. **Waste Incineration**	Waste incineration
LAND USE, LAND-USE CHANGE AND FORESTRY	Emissions and removals resulting from:
a. **Forest Land**	Managed forests including growth, harvests and fires, and from land conversion to forests
b. **Cropland**	Mineral and organic cropland soils management, liming, and land conversion to cropland (CO_2)
c. **Grassland**	Land conversion to grasslands
d. **Wetlands**	Peatlands management for peat extraction (under development)
e. **Settlements**	Urban trees and the conversion of vegetated land to urban lands

TABLE A12-2: 1990–2003 Greenhouse Gas Emissions Summary for Newfoundland and Labrador

kt CO_2 eq

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
TOTAL	**9 340**	**8 170**	**8 140**	**8 200**	**7 220**	**8 130**	**8 230**	**8 750**	**10 200**	**8 860**	**8 630**	**9 430**	**11 300**	**10 900**
ENERGY	**8 840**	**7 670**	**7 630**	**7 680**	**6 680**	**7 590**	**7 690**	**8 190**	**9 590**	**8 290**	**8 120**	**8 910**	**10 800**	**10 300**
a. Stationary Combustion Sources	**5 420**	**4 540**	**4 530**	**4 550**	**3 650**	**4 500**	**4 490**	**4 940**	**6 310**	**4 840**	**4 410**	**5 190**	**6 960**	**6 350**
Electricity and Heat Generation	1 610	1 280	1 480	1 340	716	1 250	1 160	1 210	1 020	936	919	X	X	X
Fossil Fuel Industries	1 000	1 000	860	1 100	570	940	1 100	1 300	3 200	2 000	1 400	1 400	2 900	2 400
Mining	1 060	716	685	614	907	900	927	1 050	895	641	885	X	X	X
Manufacturing Industries	497	386	310	330	299	315	269	282	211	252	241	257	283	290
Construction	33.4	23.7	27.2	22.4	17.7	17.6	14.5	14.8	13.1	12.3	10.4	19.2	27.8	26.3
Commercial & Institutional	326	317	307	329	341	321	312	364	306	316	325	385	445	515
Residential	820	760	800	800	740	690	670	690	610	580	550	580	620	580
Agriculture & Forestry	25.1	41.9	60.5	55.7	54.3	57.4	59.0	75.5	76.0	69.5	47.8	X	X	X
b. Transportation	**3 400**	**3 100**	**3 100**	**3 100**	**3 000**	**3 100**	**3 200**	**3 300**	**3 300**	**3 400**	**3 600**	**3 600**	**3 600**	**3 800**
Domestic Aviation	470	350	400	340	330	360	360	350	320	300	370	360	320	410
Road Transportation	1 900	1 900	1 850	1 900	1 950	1 890	1 870	1 870	1 870	1 960	2 010	2 000	2 070	2 140
Light-Duty Gasoline Vehicles	772	744	744	749	751	720	701	683	655	666	647	639	650	653
Light-Duty Gasoline Trucks	565	568	590	614	635	629	633	638	645	696	698	703	730	769
Heavy-Duty Gasoline Vehicles	74.6	75.3	78.3	81.4	83.9	82.8	74.6	56.5	67.9	47.2	44.4	36.2	38.8	35.9
Motorcycles	6.77	6.05	5.49	5.35	5.18	4.62	4.52	4.33	4.24	4.27	4.27	4.20	3.58	3.41
Light-Duty Diesel Vehicles	3.51	3.23	3.05	2.87	2.68	2.39	2.20	2.06	1.93	1.98	1.75	1.89	1.98	2.09
Light-Duty Diesel Trucks	13.8	12.6	9.42	8.16	7.14	5.37	4.11	6.00	4.34	6.99	7.07	10.5	11.9	14.6
Heavy-Duty Diesel Vehicles	459	484	422	435	464	442	452	482	487	535	608	609	632	664
Propane & Natural Gas Vehicles	1.4	1.7	1.4	5.8	1.5	2.4	2.3	2.6	1.4	4.2	1.0	1.0	0.34	0.30
Railways	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Domestic Marine	710	660	610	540	470	560	610	620	650	690	690	620	580	420
Others	400	200	200	300	300	300	300	400	400	400	500	600	600	800
Off-Road Gasoline	70	70	70	60	40	40	40	30	30	40	70	80	70	40
Off-Road Diesel	300	200	200	300	300	200	300	400	400	400	500	500	600	700
Pipelines	–	–	–	–	–	–	–	–	–	–	–	–	–	35
c. Fugitive Sources	–	–	–	–	–	–	–	–	**18.2**	**74.3**	**118**	**126**	**187**	**220**
Coal Mining	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oil and Natural Gas	–	–	–	–	–	–	–	–	18.2	74.3	118	126	187	220
INDUSTRIAL PROCESSES	**76.9**	**62.7**	**67.5**	**71.9**	**78.2**	**78.5**	**79.2**	**91.0**	**87.6**	**89.1**	**22.8**	**22.6**	**25.4**	**29.3**
a. Mineral Production[1]	**58**	**48**	**53**	**58**	**64**	**64**	**64**	**75**	**74**	**68**	–	–	–	–
Cement	58	48	53	58	64	64	64	75	74	68	–	–	–	–
Lime	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**19**	**15**	**14**	**14**	**14**	**15**	**15**	**16**	**14**	**21**	**23**	**23**	**25**	**29**
SOLVENT & OTHER PRODUCT USE	**8.7**	**8.7**	**8.7**	**8.7**	**8.7**	**8.5**	**8.4**	**8.3**	**8.1**	**8.0**	**8.0**	**7.9**	**7.8**	**7.8**
AGRICULTURE	**48**	**48**	**49**	**48**	**46**	**48**	**48**	**46**	**45**	**45**	**44**	**49**	**50**	**49**
a. Enteric Fermentation	**18.9**	**18.8**	**19.1**	**18.7**	**18.1**	**18.3**	**18.3**	**17.8**	**17.4**	**17.4**	**16.8**	**19.7**	**19.7**	**19.2**
b. Manure Management	**15**	**14**	**15**	**14**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**15**	**15**	**15**
c. Agricultural Soils	**15**	**14**	**16**	**15**	**15**	**16**	**16**	**15**	**14**	**14**	**14**	**15**	**16**	**15**
Direct Sources	11	11	12	11	11	12	12	11	11	10	10	11	12	11
Indirect Sources	4	4	4	4	4	4	4	4	4	4	4	4	4	4
WASTE	**360**	**370**	**380**	**390**	**400**	**410**	**410**	**420**	**420**	**430**	**430**	**440**	**450**	**450**
a. Solid Waste Disposal on Land	**340**	**350**	**360**	**360**	**370**	**380**	**380**	**390**	**400**	**400**	**410**	**420**	**420**	**430**
b. Wastewater Handling	**19**	**19**	**19**	**19**	**19**	**19**	**18**	**18**	**18**	**18**	**17**	**17**	**17**	**17**
c. Waste Incineration	**8.4**	**8.4**	**8.5**	**8.5**	**8.4**	**8.3**	**8.2**	**8.0**	**7.9**	**7.8**	**7.7**	**7.6**	**7.6**	**7.6**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-3: 2003 Greenhouse Gas Emissions Summary for Newfoundland and Labrador

GHG Source Category	Greenhouse Gases CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			21		310				
Unit	kt	kt	kt CO_2 eq	kt	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq
TOTAL	9 820	35	740	1.0	320	–	–	–	10 900
ENERGY	**9 780**	**10**	**300**	**0.9**	**300**	–	–	–	**10 300**
a. Stationary Combustion Sources	**6 110**	**9**	**200**	**0.2**	**50**	–	–	–	**6 350**
Electricity and Heat Generation	X	X	X	X	X	–	–	–	X
Fossil Fuel Industries	2 300	4	80	0.05	20	–	–	–	2 400
Mining	X	X	X	X	X	–	–	–	X
Manufacturing Industries	288	0.01	0.2	0.01	2	–	–	–	290
Construction	26.2	0.00	0.01	0.00	0.1	–	–	–	26.3
Commercial & Institutional	512	0.01	0.1	0.01	3	–	–	–	515
Residential	441	6	100	0.06	20	–	–	–	580
Agriculture & Forestry	X	X	X	X	X	–	–	–	X
b. Transportation	**3 550**	**0.3**	**6**	**0.7**	**200**	–	–	–	**3 800**
Domestic Aviation	397	0.02	0.3	0.04	10	–	–	–	410
Road Transportation	2 060	0.16	3.4	0.26	79	–	–	–	2 140
Light-Duty Gasoline Vehicles	627	0.04	0.90	0.08	25	–	–	–	653
Light-Duty Gasoline Trucks	721	0.08	1.7	0.15	46	–	–	–	769
Heavy-Duty Gasoline Vehicles	34.2	0.00	0.10	0.01	1.6	–	–	–	35.9
Motorcycles	3.34	0.00	0.06	0.00	0.02	–	–	–	3.41
Light-Duty Diesel Vehicles	2.04	0.00	0.00	0.00	0.05	–	–	–	2.09
Light-Duty Diesel Trucks	14.3	0.00	0.01	0.00	0.3	–	–	–	14.6
Heavy-Duty Diesel Vehicles	657	0.03	0.7	0.02	6	–	–	–	664
Propane & Natural Gas Vehicles	0.30	0.00	0.00	0.00	0.00	–	–	–	0.30
Railways	–	–	–	–	–	–	–	–	–
Domestic Marine	373	0.02	0.4	0.1	40	–	–	–	420
Others	720	0.08	2	0.3	80	–	–	–	800
Off-Road Gasoline	40	0.05	1	0.00	0.3	–	–	–	40
Off-Road Diesel	650	0.03	0.7	0.3	80	–	–	–	700
Pipelines	33.3	0.00	0.03	0.01	2	–	–	–	34.9
c. Fugitive Sources	**130**	**4.2**	**89**	–	–	–	–	–	**220**
Coal Mining	–	–	–	–	–	–	–	–	–
Oil and Natural Gas	130	4.2	89	–	–	–	–	–	220
INDUSTRIAL PROCESSES	**29.3**	–	–	–	–	–	–	–	**29.3**
a. Mineral Production[1]	–	–	–	–	–	–	–	–	–
Cement	–	–	–	–	–	–	–	–	–
Lime	–	–	–	–	–	–	–	–	–
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	29	–	–	–	–	–	–	–	29
SOLVENT & OTHER PRODUCT USE	–	–	–	**0.03**	**7.8**	–	–	–	**7.8**
AGRICULTURE	–	**1.19**	**24.9**	**0.08**	**24**	–	–	–	**49**
a. Enteric Fermentation	–	**0.92**	**19.2**	–	–	–	–	–	**19.2**
b. Manure Management	–	**0.27**	**5.7**	**0.03**	**8.9**	–	–	–	**15**
c. Agricultural Soils	–	–	–	**0.05**	**15**	–	–	–	**15**
Direct Sources	–	–	–	0.04	11	–	–	–	11
Indirect Sources	–	–	–	0.01	4	–	–	–	4
WASTE	**6.1**	**20**	**430**	**0.06**	**20**	–	–	–	**450**
a. Solid Waste Disposal on Land	–	**20**	**430**	–	–	–	–	–	**430**
b. Wastewater Handling	–	**0.04**	**0.90**	**0.05**	**20**	–	–	–	**17**
c. Waste Incineration	**6.1**	–	–	**0.01**	**1**	–	–	–	**7.6**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-4: 1990–2003 Greenhouse Gas Emissions Summary for Prince Edward Island

GHG Source Category	kt CO_2 eq													
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
TOTAL	**1930**	**1890**	**1910**	**1880**	**1870**	**1830**	**1960**	**1990**	**1950**	**1960**	**2100**	**2000**	**2010**	**2090**
ENERGY	**1460**	**1430**	**1420**	**1420**	**1410**	**1360**	**1480**	**1520**	**1470**	**1470**	**1620**	**1540**	**1530**	**1610**
a. Stationary Combustion Sources	**749**	**713**	**708**	**709**	**676**	**649**	**693**	**747**	**668**	**620**	**751**	**696**	**686**	**743**
Electricity and Heat Generation	102	92.2	51.7	74.8	58.8	39.1	27.4	37.1	11.1	19.5	56.0	X	X	X
Fossil Fuel Industries	0.29	–	1.4	1.7	1.1	1.7	1.7	1.7	2.6	0.59	2.1	4.2	–	–
Mining	0.77	0.77	1.07	–	–	0.61	1.38	1.38	1.53	2.25	4.94	X	X	X
Manufacturing Industries	54.6	69.6	76.6	79.4	79.8	71.5	90.9	110.0	90.8	56.2	133	124	119	137
Construction	11.1	10.2	9.77	8.96	8.80	6.53	5.83	5.29	6.64	5.97	6.81	5.39	5.98	4.36
Commercial & Institutional	161	157	160	158	161	180	184	192	177	171	198	197	212	241
Residential	400	360	380	360	340	310	330	350	330	320	320	300	310	300
Agriculture & Forestry	19.1	19.6	27.5	28.0	27.4	40.6	47.2	50.8	49.3	44.2	32.1	X	X	X
b. Transportation	**710**	**720**	**710**	**710**	**730**	**710**	**780**	**770**	**800**	**850**	**870**	**840**	**850**	**870**
Domestic Aviation	13	10	7.2	7.2	6.9	5.6	8.5	9.0	8.4	8.2	7.6	7.4	7.3	9.4
Road Transportation	540	537	537	546	567	579	594	611	646	684	672	662	685	701
Light-Duty Gasoline Vehicles	286	273	264	258	256	254	248	252	249	275	259	255	264	262
Light-Duty Gasoline Trucks	146	149	154	160	170	179	192	200	215	240	242	244	263	273
Heavy-Duty Gasoline Vehicles	21.0	24.3	27.9	31.6	35.7	39.9	42.1	39.2	48.7	28.1	24.9	21.0	22.6	19.7
Motorcycles	1.06	1.10	0.99	0.97	0.97	1.00	1.13	1.16	0.63	0.76	0.62	0.61	0.62	0.54
Light-Duty Diesel Vehicles	2.76	2.74	2.76	2.79	2.85	2.90	2.73	2.69	2.68	2.83	2.64	2.88	2.84	2.96
Light-Duty Diesel Trucks	2.25	1.91	1.58	1.39	1.30	1.08	0.96	0.97	0.99	1.83	1.83	1.90	1.81	1.97
Heavy-Duty Diesel Vehicles	80.3	84.5	85.1	90.2	101	100	106	113	128	133	140	135	130	141
Propane & Natural Gas Vehicles	1.1	1.1	0.91	0.76	0.15	0.91	1.2	1.4	0.76	2.2	0.70	1.6	0.04	0.04
Railways	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Domestic Marine	90	110	130	110	91	63	110	72	66	74	85	85	79	85
Others	70	60	40	40	70	70	70	80	80	90	100	90	80	70
Off-Road Gasoline	10	9	8	10	20	10	20	10	8	8	10	10	9	9
Off-Road Diesel	60	50	30	30	50	60	50	60	70	80	90	80	70	60
Pipelines	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Fugitive Sources	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Coal Mining	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oil and Natural Gas	–	–	–	–	–	–	–	–	–	–	–	–	–	–
INDUSTRIAL PROCESSES	**2.82**	**2.68**	**3.10**	**3.24**	**3.53**	**2.96**	**2.96**	**2.96**	**2.82**	**3.18**	**2.85**	**2.58**	**2.47**	**2.47**
a. Mineral Production[1]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cement	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lime	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**2.8**	**2.7**	**3.1**	**3.2**	**3.5**	**3.0**	**3.0**	**3.0**	**2.8**	**3.2**	**2.8**	**2.6**	**2.5**	**2.5**
SOLVENT & OTHER PRODUCT USE	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.1**	**2.0**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**
AGRICULTURE	**380**	**370**	**410**	**380**	**380**	**380**	**390**	**390**	**390**	**390**	**390**	**370**	**380**	**380**
a. Enteric Fermentation	**154**	**150**	**148**	**148**	**148**	**148**	**147**	**148**	**149**	**150**	**146**	**136**	**135**	**135**
b. Manure Management	**63**	**62**	**61**	**60**	**61**	**62**	**62**	**59**	**60**	**61**	**60**	**59**	**59**	**59**
c. Agricultural Soils	**170**	**160**	**200**	**170**	**170**	**170**	**190**	**180**	**180**	**180**	**180**	**170**	**190**	**190**
Direct Sources	130	120	160	130	130	130	140	140	140	140	140	130	140	140
Indirect Sources	40	40	40	40	40	40	40	40	40	40	40	40	40	40
WASTE	**77**	**78**	**79**	**81**	**82**	**84**	**85**	**87**	**88**	**90**	**91**	**92**	**94**	**95**
a. Solid Waste Disposal on Land	**61**	**62**	**64**	**65**	**67**	**68**	**69**	**71**	**72**	**73**	**75**	**76**	**77**	**79**
b. Wastewater Handling	**7.1**	**7.1**	**7.1**	**7.2**	**7.2**	**7.3**	**7.4**	**7.4**	**7.4**	**7.4**	**7.4**	**7.4**	**7.4**	**7.5**
c. Waste Incineration	**8.5**	**8.5**	**8.5**	**8.6**	**8.7**	**8.7**	**8.8**	**8.8**	**8.8**	**8.9**	**8.9**	**8.9**	**8.9**	**9.0**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-5: 2003 Greenhouse Gas Emissions Summary for Prince Edward Island

	Greenhouse Gases								
GHG Source Category	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**1530**	**14**	**290**	**0.89**	**270**	–	–	–	**2090**
ENERGY	**1520**	**2**	**40**	**0.2**	**50**	–	–	–	**1610**
a. Stationary Combustion Sources	**700**	**2**	**30**	**0.03**	**8**	–	–	–	**743**
Electricity and Heat Generation	X	X	X	X	X	–	–	–	X
Fossil Fuel Industries	–	–	–	–	–	–	–	–	–
Mining	X	X	X	X	X	–	–	–	X
Manufacturing Industries	136	0.01	0.1	0.00	0.9	–	–	–	137
Construction	4.34	0.00	0.00	0.00	0.02	–	–	–	4.36
Commercial & Institutional	240	0.00	0.05	0.00	1	–	–	–	241
Residential	257	2	30	0.02	6	–	–	–	300
Agriculture & Forestry	X	X	X	X	X	–	–	–	X
b. Transportation	**822**	**0.1**	**2**	**0.1**	**50**	–	–	–	**870**
Domestic Aviation	9.12	0.00	0.02	0.00	0.3	–	–	–	9
Road Transportation	670	0.06	1.3	0.10	30	–	–	–	701
Light-Duty Gasoline Vehicles	251	0.02	0.42	0.03	11	–	–	–	262
Light-Duty Gasoline Trucks	255	0.03	0.62	0.06	17	–	–	–	273
Heavy-Duty Gasoline Vehicles	18.8	0.00	0.06	0.00	0.86	–	–	–	19.7
Motorcycles	0.53	0.00	0.01	0.00	0.00	–	–	–	0.54
Light-Duty Diesel Vehicles	2.89	0.00	0.00	0.00	0.07	–	–	–	2.96
Light-Duty Diesel Trucks	1.93	0.00	0.00	0.00	0.04	–	–	–	1.97
Heavy-Duty Diesel Vehicles	140	0.01	0.1	0.00	1	–	–	–	141
Propane & Natural Gas Vehicles	0.04	0.00	0.00	0.00	0.00	–	–	–	0.04
Railways	–	–	–	–	–	–	–	–	–
Domestic Marine	76.4	0.00	0.09	0.03	9	–	–	–	85
Others	67	0.01	0.3	0.02	7	–	–	–	70
Off-Road Gasoline	9	0.01	0.2	0.00	0.06	–	–	–	9
Off-Road Diesel	58	0.00	0.06	0.02	7	–	–	–	60
Pipelines	–	–	–	–	–	–	–	–	–
c. Fugitive Sources	–	–	–	–	–	–	–	–	–
Coal Mining	–	–	–	–	–	–	–	–	–
Oil and Natural Gas	–	–	–	–	–	–	–	–	–
INDUSTRIAL PROCESSES	**2.47**	–	–	–	–	–	–	–	**2.47**
a. Mineral Production[1]	–	–	–	–	–	–	–	–	–
Cement	–	–	–	–	–	–	–	–	–
Lime	–	–	–	–	–	–	–	–	–
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**2.5**	–	–	–	–	–	–	–	**2.5**
SOLVENT & OTHER PRODUCT USE	–	–	–	**0.01**	**2.1**	–	–	–	**2.1**
AGRICULTURE	–	**8.01**	**168**	**0.68**	**210**	–	–	–	**380**
a. Enteric Fermentation	–	**6.41**	**135**	–	–	–	–	–	**135**
b. Manure Management	–	**1.6**	**34**	**0.08**	**25**	–	–	–	**59**
c. Agricultural Soils	–	–	–	**0.60**	**190**	–	–	–	**190**
Direct Sources	–	–	–	0.46	140	–	–	–	140
Indirect Sources	–	–	–	0.1	40	–	–	–	40
WASTE	**7.5**	**3.9**	**82**	**0.02**	**6**	–	–	–	**95**
a. Solid Waste Disposal on Land	–	**3.7**	**79**	–	–	–	–	–	**79**
b. Wastewater Handling	–	**0.15**	**3.2**	**0.01**	**4**	–	–	–	**7.5**
c. Waste Incineration	**7.5**	–	–	**0.01**	**1**	–	–	–	**9.0**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-6: 1990–2003 Greenhouse Gas Emissions Summary for Nova Scotia

kt CO_2 eq

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
TOTAL	**19 200**	**19 100**	**19 600**	**19 400**	**18 900**	**18 800**	**18 900**	**19 500**	**19 600**	**20 100**	**21 200**	**20 400**	**19 800**	**21 200**
ENERGY	**17 800**	**17 700**	**18 200**	**18 100**	**17 600**	**17 300**	**17 500**	**18 100**	**18 000**	**18 500**	**19 700**	**19 000**	**18 300**	**19 600**
a. Stationary Combustion Sources	**11 500**	**11 400**	**12 100**	**11 900**	**11 400**	**11 200**	**11 500**	**12 200**	**12 100**	**12 400**	**13 500**	**13 000**	**12 200**	**13 000**
Electricity and Heat Generation	6 830	7 000	7 380	7 310	7 120	6 900	7 100	7 530	7 800	8 060	8 830	X	X	X
Fossil Fuel Industries	710	800	790	910	600	700	730	710	700	570	950	830	1 200	1 500
Mining	35.5	32.5	31.8	22.3	29.7	33.4	38.5	41.0	46.8	48.1	53.7	X	X	X
Manufacturing Industries	716	625	637	642	767	874	805	761	782	802	661	509	691	628
Construction	50.0	36.9	31.6	25.8	30.1	35.4	28.6	29.6	36.0	32.0	28.2	37.3	55.0	52.1
Commercial & Institutional	810	794	948	789	735	817	809	946	756	865	922	1 070	1 040	1 280
Residential	2 200	2 000	2 100	2 100	2 000	1 700	1 800	1 900	1 800	1 800	1 800	1 900	1 800	1 900
Agriculture & Forestry	107	191	237	154	148	203	227	250	222	209	237	X	X	X
b. Transportation	**5 100**	**4 900**	**4 900**	**5 100**	**5 200**	**5 300**	**5 100**	**5 200**	**5 400**	**5 800**	**5 700**	**5 500**	**5 600**	**6 100**
Domestic Aviation	400	400	360	380	370	380	360	340	350	360	350	320	350	370
Road Transportation	3 610	3 410	3 520	3 620	3 550	3 820	3 820	3 780	3 740	4 160	4 100	4 010	4 120	4 290
Light-Duty Gasoline Vehicles	1 680	1 560	1 570	1 610	1 540	1 650	1 580	1 550	1 370	1 600	1 460	1 480	1 500	1 510
Light-Duty Gasoline Trucks	936	906	955	1 010	1 010	1 120	1 150	1 160	1 230	1 390	1 440	1 340	1 400	1 470
Heavy-Duty Gasoline Vehicles	136	129	133	138	133	144	141	121	137	87.7	96.4	69.2	69.5	69.1
Motorcycles	12.0	11.5	11.0	11.1	9.90	9.78	12.4	8.74	10.2	9.79	9.32	8.10	8.09	7.90
Light-Duty Diesel Vehicles	26.3	25.1	26.0	27.0	26.2	28.5	28.1	28.0	25.0	29.0	28.1	30.2	32.4	36.1
Light-Duty Diesel Trucks	20.8	16.9	15.1	12.9	11.2	9.64	8.33	9.60	8.32	12.0	15.9	15.1	18.2	22.4
Heavy-Duty Diesel Vehicles	790	757	797	800	826	854	896	894	951	1 010	1 040	1 060	1 080	1 170
Propane & Natural Gas Vehicles	7.4	7.4	6.7	8.1	2.9	5.2	6.4	8.8	5.0	14	4.1	5.0	3.9	3.9
Railways	70	50	60	60	60	50	30	40	40	60	80	70	80	200
Domestic Marine	610	700	610	600	630	570	570	600	660	720	670	540	500	680
Others	400	400	400	400	600	500	300	500	600	500	600	600	600	600
Off-Road Gasoline	70	60	50	50	200	50	40	70	200	40	50	90	50	20
Off-Road Diesel	300	300	300	400	400	400	300	400	300	500	500	500	600	600
Pipelines	–	–	–	–	–	–	–	–	–	–	–	–	–	120
c. Fugitive Sources	**1 170**	**1 340**	**1 200**	**1 080**	**972**	**835**	**835**	**690**	**511**	**335**	**394**	**477**	**480**	**453**
Coal Mining	1 000	1 000	1 000	1 000	1 000	800	800	700	500	300	300	300	300	300
Oil and Natural Gas	–	–	2.69	4.83	6.04	5.71	4.89	3.56	3.56	1.61	144	207	211	184
INDUSTRIAL PROCESSES	**276**	**238**	**178**	**180**	**207**	**302**	**270**	**187**	**335**	**319**	**286**	**195**	**285**	**316**
a. Mineral Production[1]	**180**	**160**	**110**	**120**	**150**	**230**	**200**	**120**	**220**	**230**	**220**	**130**	**220**	**220**
Cement	180	160	110	120	150	230	200	120	220	230	220	130	220	220
Lime	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–	**6.02**	**0.88**	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–	6.02	0.88	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**100**	**77**	**68**	**59**	**56**	**77**	**70**	**71**	**110**	**88**	**69**	**62**	**68**	**97**
SOLVENT & OTHER PRODUCT USE	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**
AGRICULTURE	**520**	**510**	**520**	**510**	**530**	**530**	**540**	**520**	**510**	**500**	**500**	**480**	**490**	**490**
a. Enteric Fermentation	**216**	**216**	**213**	**212**	**212**	**212**	**210**	**213**	**203**	**199**	**194**	**187**	**186**	**185**
b. Manure Management	**100**	**100**	**97**	**96**	**96**	**97**	**97**	**95**	**93**	**95**	**93**	**90**	**89**	**88**
c. Agricultural Soils	**210**	**200**	**210**	**200**	**220**	**220**	**230**	**210**	**210**	**210**	**210**	**200**	**210**	**220**
Direct Sources	160	150	160	150	170	170	180	160	160	150	160	150	160	170
Indirect Sources	50	50	50	50	50	50	50	50	50	50	50	50	50	50
WASTE	**590**	**610**	**620**	**630**	**610**	**630**	**650**	**670**	**680**	**690**	**710**	**720**	**740**	**770**
a. Solid Waste Disposal on Land	**540**	**550**	**560**	**580**	**560**	**570**	**590**	**610**	**620**	**640**	**650**	**670**	**680**	**720**
b. Wastewater Handling	**39**	**39**	**39**	**39**	**39**	**40**	**40**	**40**	**40**	**40**	**40**	**40**	**40**	**40**
c. Waste Incineration	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-7: 2003 Greenhouse Gas Emissions Summary for Nova Scotia

GHG Source Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			21		310				
Unit	kt	kt	kt CO_2 eq	kt	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq
TOTAL	**19 000**	**70**	**1 500**	**2.2**	**680**	–	–	–	**21 200**
ENERGY	**18 700**	**20**	**500**	**1**	**400**	–	–	–	**19 600**
a. Stationary Combustion Sources	**12 700**	**9**	**200**	**0.3**	**90**	–	–	–	**13 000**
Electricity and Heat Generation	X	X	X	X	X	–	–	–	X
Fossil Fuel Industries	1 500	2	30	0.02	7	–	–	–	1 500
Mining	X	X	X	X	X	–	–	–	X
Manufacturing Industries	616	0.08	2	0.03	10	–	–	–	628
Construction	51.8	0.00	0.02	0.00	0.3	–	–	–	52.1
Commercial & Institutional	1 270	0.02	0.3	0.03	8	–	–	–	1 280
Residential	1 720	8	200	0.09	30	–	–	–	1 900
Agriculture & Forestry	X	X	X	X	X	–	–	–	X
b. Transportation	**5 860**	**0.5**	**10**	**0.9**	**300**	–	–	–	**6 100**
Domestic Aviation	360	0.01	0.3	0.04	10	–	–	–	370
Road Transportation	4 120	0.33	6.9	0.52	160	–	–	–	4 290
Light-Duty Gasoline Vehicles	1 450	0.10	2.2	0.19	59	–	–	–	1 510
Light-Duty Gasoline Trucks	1 380	0.15	3.1	0.28	88	–	–	–	1 470
Heavy-Duty Gasoline Vehicles	65.9	0.01	0.19	0.01	3.0	–	–	–	69.1
Motorcycles	7.72	0.01	0.13	0.00	0.05	–	–	–	7.90
Light-Duty Diesel Vehicles	35.3	0.00	0.02	0.00	0.8	–	–	–	36.1
Light-Duty Diesel Trucks	21.9	0.00	0.01	0.00	0.5	–	–	–	22.4
Heavy-Duty Diesel Vehicles	1 160	0.06	1	0.03	10	–	–	–	1 170
Propane & Natural Gas Vehicles	3.88	0.00	0.03	0.00	0.02	–	–	–	3.9
Railways	152	0.01	0.2	0.06	20	–	–	–	200
Domestic Marine	658	0.06	1	0.1	20	–	–	–	680
Others	570	0.06	1	0.2	70	–	–	–	600
Off-Road Gasoline	20	0.02	1	0.00	0.1	–	–	–	20
Off-Road Diesel	530	0.03	0.6	0.2	70	–	–	–	600
Pipelines	11.6	0.01	0.25	0.0	0.1	–	–	–	12.0
c. Fugitive Sources	**160**	**14**	**300**	–	–	–	–	–	**453**
Coal Mining	–	10	300	–	–	–	–	–	300
Oil and Natural Gas	160	1.4	28	–	–	–	–	–	184
INDUSTRIAL PROCESSES	**316**	–	–	–	–	–	–	–	**316**
a. Mineral Production[1]	**220**	–	–	–	–	–	–	–	**220**
Cement	220	–	–	–	–	–	–	–	220
Lime	–	–	–	–	–	–	–	–	–
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**97**	–	–	–	–	–	–	–	**97**
SOLVENT & OTHER PRODUCT USE	–	–	–	**0.05**	**14**	–	–	–	**14**
AGRICULTURE	–	**10.9**	**228**	**0.85**	**260**	–	–	–	**490**
a. Enteric Fermentation	–	**8.82**	**185**	–	–	–	–	–	**185**
b. Manure Management	–	**2.0**	**43**	**0.15**	**45**	–	–	–	**88**
c. Agricultural Soils	–	–	–	**0.70**	**220**	–	–	–	**220**
Direct Sources	–	–	–	0.53	170	–	–	–	170
Indirect Sources	–	–	–	0.2	50	–	–	–	50
WASTE	**14**	**35**	**730**	**0.1**	**30**	–	–	–	**770**
a. Solid Waste Disposal on Land	–	**34**	**720**	–	–	–	–	–	**720**
b. Wastewater Handling	–	**0.50**	**11**	**0.09**	**30**	–	–	–	**40**
c. Waste Incineration	**14**	–	–	**0.01**	**3**	–	–	–	**16**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-8: 1990–2003 Greenhouse Gas Emissions Summary for New Brunswick

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	kt CO_2 eq													
TOTAL	**15 800**	**15 200**	**15 800**	**15 100**	**16 300**	**16 800**	**16 600**	**18 900**	**19 700**	**18 900**	**20 100**	**22 400**	**21 400**	**21 000**
ENERGY	**14 700**	**14 100**	**14 700**	**13 900**	**15 200**	**15 600**	**15 300**	**17 700**	**18 500**	**17 600**	**18 800**	**21 100**	**19 900**	**19 500**
a. Stationary Combustion Sources	**10 600**	**9 990**	**10 500**	**9 630**	**10 700**	**11 100**	**10 600**	**12 900**	**13 500**	**12 300**	**13 200**	**15 600**	**14 400**	**14 000**
Electricity and Heat Generation	6 000	5 450	6 100	5 130	6 230	6 850	6 060	8 340	9 460	8 200	8 560	X	X	X
Fossil Fuel Industries	1 100	1 100	1 100	1 200	1 300	1 000	1 400	1 300	1 200	1 300	1 600	2 800	3 200	3 000
Mining	127	82.4	96.3	103	115	117	153	121	98.5	97.2	134	X	X	X
Manufacturing Industries	1 420	1 410	1 370	1 410	1 390	1 460	1 420	1 350	1 220	1 250	1 340	1 290	1 240	1 250
Construction	68.5	53.1	53.3	34.7	41.4	40.9	40.0	48.9	39.0	36.6	39.9	26.4	18.6	12.5
Commercial & Institutional	587	655	507	461	505	555	495	593	504	491	614	580	494	600
Residential	1 200	1 200	1 200	1 200	1 100	920	930	960	840	820	850	730	740	760
Agriculture & Forestry	53.9	65.0	81.4	87.4	86.9	131.0	110.0	119.0	104.0	101.0	65.8	X	X	X
b. Transportation	**4 100**	**4 100**	**4 200**	**4 300**	**4 500**	**4 500**	**4 700**	**4 800**	**5 000**	**5 300**	**5 600**	**5 500**	**5 500**	**5 400**
Domestic Aviation	76	73	72	68	79	83	87	140	140	150	160	150	130	130
Road Transportation	3 280	3 200	3 250	3 360	3 530	3 540	3 650	3 710	3 750	4 040	3 920	3 820	3 960	3 970
Light-Duty Gasoline Vehicles	1 570	1 500	1 490	1 490	1 500	1 430	1 450	1 450	1 470	1 480	1 350	1 370	1 400	1 360
Light-Duty Gasoline Trucks	704	713	754	795	847	849	911	945	942	1 040	1 050	1 070	1 110	1 120
Heavy-Duty Gasoline Vehicles	102	104	111	118	126	126	137	110	126	69.3	85.4	68.7	85.8	85.6
Motorcycles	6.68	6.48	6.45	6.47	6.77	6.48	7.00	7.14	7.62	7.36	7.87	8.46	8.25	8.31
Light-Duty Diesel Vehicles	18.7	18.2	18.5	18.7	19.0	18.2	18.6	18.9	19.1	18.0	17.8	18.4	19.9	20.8
Light-Duty Diesel Trucks	21.1	16.8	14.0	12.4	11.5	10.4	8.86	16.1	14.5	18.5	15.6	16.5	17.0	18.0
Heavy-Duty Diesel Vehicles	847	837	850	910	1 010	1 090	1 100	1 150	1 160	1 390	1 390	1 270	1 310	1 360
Propane & Natural Gas Vehicles	5.0	5.2	5.2	8.7	4.0	8.1	8.2	10	9.1	16	6.8	8.0	1.6	1.4
Railways	100	100	100	100	100	100	100	100	200	200	200	300	300	300
Domestic Marine	270	260	290	280	300	300	310	310	330	360	400	430	400	370
Others	300	400	400	400	500	500	500	500	600	600	800	900	800	700
Off-Road Gasoline	10	10	10	20	10	10	10	20	20	10	70	70	40	100
Off-Road Diesel	300	400	400	400	500	400	500	500	600	500	800	800	700	600
Pipelines	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Fugitive Sources	**1.46**	**1.36**	**0.97**	**1.00**	**0.90**	**0.71**	**0.74**	**0.48**	**0.74**	**0.74**	**29.8**	**31.2**	**31.2**	**31.2**
Coal Mining	1	1	1	1	0.9	0.7	0.7	0.5	0.7	0.7	0.6	0.4	0.4	0.4
Oil and Natural Gas	–	–	–	–	–	–	–	–	–	–	29.3	30.7	30.7	30.7
INDUSTRIAL PROCESSES	**152**	**170**	**178**	**191**	**132**	**254**	**247**	**246**	**240**	**236**	**226**	**260**	**449**	**419**
a. Mineral Production[1]	**76**	**77**	**79**	**85**	**88**	**91**	**88**	**92**	**92**	**96**	**100**	**92**	**95**	**83**
Cement	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lime	80	80	80	90	90	90	90	90	90	100	100	90	90	80
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**75**	**92**	**100**	**110**	**44**	**160**	**160**	**150**	**150**	**140**	**120**	**170**	**350**	**340**
SOLVENT & OTHER PRODUCT USE	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**
AGRICULTURE	**430**	**420**	**430**	**420**	**420**	**430**	**430**	**420**	**430**	**430**	**430**	**430**	**440**	**440**
a. Enteric Fermentation	**175**	**173**	**172**	**171**	**170**	**170**	**169**	**164**	**164**	**163**	**159**	**156**	**154**	**154**
b. Manure Management	**74**	**73**	**74**	**73**	**74**	**74**	**75**	**73**	**75**	**77**	**77**	**80**	**79**	**78**
c. Agricultural Soils	**180**	**170**	**180**	**180**	**170**	**180**	**190**	**180**	**190**	**190**	**200**	**190**	**210**	**210**
Direct Sources	140	130	140	140	130	140	140	140	140	140	150	150	160	160
Indirect Sources	40	40	40	40	40	40	40	40	50	50	50	50	50	50
WASTE	**500**	**510**	**520**	**530**	**540**	**550**	**560**	**580**	**590**	**600**	**610**	**620**	**630**	**640**
a. Solid Waste Disposal on Land	**450**	**460**	**470**	**480**	**490**	**500**	**510**	**520**	**530**	**540**	**550**	**560**	**570**	**580**
b. Wastewater Handling	**50**	**51**	**51**	**51**	**51**	**51**	**51**	**51**	**51**	**51**	**51**	**51**	**51**	**51**
c. Waste Incineration	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-9: 2003 Greenhouse Gas Emissions Summary for New Brunswick

	Greenhouse Gases								
GHG Source Category	**CO_2**	**CH_4**	**CH_4**	**N_2O**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**TOTAL**
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**19 300**	**49**	**1 000**	**2.2**	**680**	–	–	–	**21 000**
ENERGY	**18 900**	**10**	**200**	**1**	**400**	–	–	–	**19 500**
a. Stationary Combustion Sources	**13 700**	**9**	**200**	**0.4**	**100**	–	–	–	**14 000**
Electricity and Heat Generation	X	X	X	X	X	–	–	–	X
Fossil Fuel Industries	3 000	0.06	1	0.03	10	–	–	–	3 000
Mining	X	X	X	X	X	–	–	–	X
Manufacturing Industries	1 220	0.2	4	0.08	30	–	–	–	1 250
Construction	12.4	0.00	0.00	0.00	0.06	–	–	–	12.5
Commercial & Institutional	595	0.01	0.2	0.01	5	–	–	–	600
Residential	545	9	200	0.1	30	–	–	–	760
Agriculture & Forestry	X	X	X	X	X	–	–	–	X
b. Transportation	**5 140**	**0.5**	**10**	**0.9**	**300**	–	–	–	**5 400**
Domestic Aviation	129.0	0.01	0.1	0.01	4	–	–	–	130
Road Transportation	3 820	0.30	6.4	0.45	140	–	–	–	3 970
Light-Duty Gasoline Vehicles	1 300	0.10	2.1	0.18	55	–	–	–	1 360
Light-Duty Gasoline Trucks	1 040	0.12	2.4	0.22	69	–	–	–	1 120
Heavy-Duty Gasoline Vehicles	81.6	0.01	0.24	0.01	3.8	–	–	–	85.6
Motorcycles	8.12	0.01	0.14	0.00	0.05	–	–	–	8.31
Light-Duty Diesel Vehicles	20.3	0.00	0.01	0.00	0.5	–	–	–	20.8
Light-Duty Diesel Trucks	17.6	0.00	0.01	0.00	0.4	–	–	–	18.0
Heavy-Duty Diesel Vehicles	1 340	0.07	1	0.04	10	–	–	–	1 360
Propane & Natural Gas Vehicles	1.36	0.00	0.01	0.00	0.01	–	–	–	1.4
Railways	249	0.01	0.3	0.1	30	–	–	–	300
Domestic Marine	332	0.02	0.4	0.1	40	–	–	–	370
Others	610	0.1	3.0	0.2	70	–	–	–	700
Off-Road Gasoline	90	0.1	2.0	0.00	0.6	–	–	–	100
Off-Road Diesel	520	0.03	0.6	0.2	60	–	–	–	600
Pipelines	–	–	–	–	–	–	–	–	–
c. Fugitive Sources	**0.01**	**1.5**	**31**	–	–	–	–	–	**31.20**
Coal Mining	–	0.02	0	–	–	–	–	–	0.4
Oil and Natural Gas	0.01	1.5	31	–	–	–	–	–	30.7
INDUSTRIAL PROCESSES	**419**	–	–	–	–	–	–	–	**419**
a. Mineral Production[1]	**83**	–	–	–	–	–	–	–	**83**
Cement	–	–	–	–	–	–	–	–	–
Lime	80	–	–	–	–	–	–	–	80
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**340**	–	–	–	–	–	–	–	**340**
SOLVENT & OTHER PRODUCT USE	–	–	–	**0.04**	**11**	–	–	–	**11**
AGRICULTURE	–	**9.18**	**193**	**0.81**	**250**	–	–	–	**440**
a. Enteric Fermentation	–	**7.32**	**154**	–	–	–	–	–	**154**
b. Manure Management	–	**1.9**	**39**	**0.12**	**39**	–	–	–	**78**
c. Agricultural Soils	–	–	–	**0.68**	**210**	–	–	–	**210**
Direct Sources	–	–	–	0.53	160	–	–	–	160
Indirect Sources	–	–	–	0.2	50	–	–	–	50
WASTE	–	**29**	**610**	**0.08**	**20**	–	–	–	**640**
a. Solid Waste Disposal on Land	–	**28**	**580**	–	–	–	–	–	**580**
b. Wastewater Handling	–	**1.3**	**28**	**0.08**	**20**	–	–	–	**51**
c. Waste Incineration	–	–	–	–	–	–	–	–	–

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-10: 1990–2003 Greenhouse Gas Emissions Summary for Quebec

kt CO_2 eq

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
TOTAL	84 300	78 500	79 300	80 000	82 600	81 700	82 500	83 100	84 200	84 200	84 800	82 900	85 500	91 500
ENERGY	58 700	53 800	55 500	55 700	58 400	57 600	58 700	59 200	60 400	60 300	61 200	59 100	61 300	67 600
a. Stationary Combustion Sources	30 000	26 600	27 600	27 000	28 000	27 200	28 400	28 100	27 800	27 200	28 300	26 600	27 500	32 500
Electricity and Heat Generation	1 510	526	946	295	502	396	425	459	1 560	1 170	580	642	581	1 950
Fossil Fuel Industries	3 700	3 000	3 100	3 300	3 600	3 300	3 500	3 400	3 500	3 300	3 600	3 600	3 600	3 800
Mining	734	805	730	798	736	824	825	870	760	759	921	836	935	935
Manufacturing Industries	12 100	10 900	10 900	10 600	11 200	10 900	11 500	11 500	11 300	11 000	11 100	10 000	10 000	10 300
Construction	458	399	371	289	275	188	191	225	188	191	190	191	254	297
Commercial & Institutional	4 270	4 180	4 500	4 650	4 730	5 070	5 000	5 000	4 670	4 710	5 720	5 760	6 520	9 060
Residential	7 000	6 400	6 600	6 700	6 700	6 300	6 700	6 300	5 600	5 900	6 000	5 300	5 400	5 800
Agriculture & Forestry	293	380	449	348	330	302	277	289	258	264	261	226	258	354
b. Transportation	28 000	27 000	28 000	28 000	30 000	30 000	30 000	31 000	32 000	33 000	32 000	32 000	33 000	35 000
Domestic Aviation	960	780	790	710	780	800	800	700	740	730	770	830	1 400	1 500
Road Transportation	24 000	23 200	24 000	24 600	25 700	26 400	26 900	27 400	28 100	28 600	28 000	27 800	28 900	29 200
Light-Duty Gasoline Vehicles	13 800	12 800	13 100	13 400	13 700	13 600	13 400	13 100	13 300	13 200	12 900	12 700	13 100	13 000
Light-Duty Gasoline Trucks	3 310	3 370	3 740	4 100	4 460	4 710	4 980	5 150	5 450	6 080	6 130	6 220	6 520	6 710
Heavy-Duty Gasoline Vehicles	521	508	542	573	603	620	849	796	844	625	625	625	628	624
Motorcycles	44.6	40.8	41.5	42.8	45.4	46.9	49.0	50.5	55.1	59.4	63.8	68.3	64.0	65.0
Light-Duty Diesel Vehicles	248	232	238	242	245	242	238	231	229	223	227	231	238	239
Light-Duty Diesel Trucks	95.2	85.6	78.9	73.7	74.4	76.1	74.6	83.8	94.1	96.2	112	90.8	87.7	84.6
Heavy-Duty Diesel Vehicles	5 900	5 980	6 060	6 110	6 560	7 090	7 270	8 000	8 100	8 350	7 970	7 780	8 210	8 450
Propane & Natural Gas Vehicles	110	110	120	86	55	46	36	45	51	35	36	56	35	32
Railways	600	600	600	600	600	600	400	500	700	900	800	800	800	800
Domestic Marine	1 400	1 400	1 400	1 100	1 300	910	930	1 100	1 600	1 300	1 400	1 600	1 400	1 000
Others	1 000	900	800	1 000	2 000	1 000	900	1 000	1 000	1 000	1 000	1 000	800	2 000
Off-Road Gasoline	400	400	300	400	300	200	200	400	200	200	200	400	300	800
Off-Road Diesel	1 000	500	500	900	1 000	1 000	600	600	800	800	1 000	500	200	1 000
Pipelines	26.2	28.2	30.8	26.6	27.4	24.5	18.1	26.1	16.4	25.2	108	203	331	357
c. Fugitive Sources	281	315	320	326	385	396	404	406	439	441	444	450	450	450
Coal Mining	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Oil and Natural Gas	281	315	320	326	385	396	404	406	439	441	444	450	450	450
INDUSTRIAL PROCESSES	12 400	12 300	11 400	11 500	11 400	11 000	10 500	10 300	10 200	10 200	9 990	10 300	10 500	10 300
a. Mineral Production[1]	1 700	1 400	1 400	1 500	1 600	1 600	1 600	1 600	1 600	1 600	1 600	1 500	1 600	1 700
Cement	1 400	1 200	1 100	1 200	1 300	1 400	1 400	1 200	1 200	1 200	1 200	1 200	1 200	1 200
Lime	300	300	300	300	300	200	200	400	400	400	400	400	400	500
b. Chemical Industry[2]	15	14	15	15	14	15	14	14	13	14	15	14	15	15
Nitric Acid Production	15	14	15	15	14	15	14	14	13	14	15	14	15	15
Adipic Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	-
c. Metal Production	9 500	10 100	9 110	9 540	9 080	8 390	8 120	7 960	7 980	7 630	7 150	7 380	7 600	7 310
Iron and Steel Production	1.15	1.16	7.66	8.80	6.24	6.71	7.88	5.78	8.03	6.57	11.7	12.1	8.30	8.29
Aluminium Production	7 130	7 350	7 440	8 030	7 550	7 050	7 270	7 220	7 100	6 800	5 910	6 090	6 050	6 090
SF_6 Used in Magnesium Smelters and Casters	2 370	2 760	1 670	1 510	1 530	1 340	837	731	875	825	1 230	1 280	1 540	1 210
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
e. Other & Undifferentiated Production[2]	1 200	770	870	480	660	940	740	730	560	920	1 200	1 300	1 300	1 300
SOLVENT & OTHER PRODUCT USE	110	110	110	110	110	110	110	110	110	110	110	110	110	110
AGRICULTURE	7 300	6 900	6 800	7 100	7 100	7 200	7 300	7 200	7 200	7 100	6 800	7 000	7 100	7 200
a. Enteric Fermentation	2 730	2 650	2 640	2 660	2 680	2 720	2 770	2 690	2 580	2 500	2 420	2 460	2 480	2 490
b. Manure Management	1 500	1 400	1 400	1 400	1 500	1 500	1 500	1 500	1 500	1 500	1 400	1 500	1 500	1 500
c. Agricultural Soils	3 100	2 800	2 800	3 000	2 900	3 000	3 000	3 000	3 100	3 100	2 900	3 100	3 100	3 100
Direct Sources	2 500	2 200	2 100	2 300	2 300	2 300	2 400	2 400	2 400	2 500	2 300	2 400	2 400	2 500
Indirect Sources	700	600	600	600	600	600	700	700	700	700	600	700	700	700
WASTE	5 800	5 300	5 500	5 700	5 600	5 800	5 900	6 200	6 400	6 500	6 700	6 300	6 400	6 400
a. Solid Waste Disposal on Land	5 400	4 900	5 100	5 300	5 200	5 400	5 500	5 800	6 000	6 100	6 300	5 900	6 000	6 000
b. Wastewater Handling	250	250	250	260	260	260	260	260	260	260	260	260	270	270
c. Waste Incineration	140	140	140	140	140	140	140	140	140	150	150	150	150	150

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

Totals may not add due to rounding.

TABLE A12-11: 2003 Greenhouse Gas Emissions Summary for Quebec

GHG Source Category	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
	Greenhouse Gases								
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**72 000**	**510**	**11 000**	**18**	**5 700**	**–**	**1 950**	**1 200**	**91 500**
ENERGY	**64 800**	**60**	**1 000**	**5**	**2 000**	**–**	**–**	**–**	**67 600**
a. Stationary Combustion Sources	**31 400**	**30**	**700**	**1**	**300**	**–**	**–**	**–**	**32 500**
Electricity and Heat Generation	1 930	0.05	1.0	0.04	10	–	–	–	1 950
Fossil Fuel Industries	3 800	0.06	1	0.05	10	–	–	–	3 800
Mining	930	0.03	0.6	0.02	5	–	–	–	935
Manufacturing Industries	10 200	0.6	10	0.3	100	–	–	–	10 300
Construction	295	0.01	0.1	0.01	2	–	–	–	297
Commercial & Institutional	9 010	0.1	3	0.2	50	–	–	–	9 060
Residential	4 970	30	700	0.4	100	–	–	–	5 800
Agriculture & Forestry	349	0.01	0.1	0.01	5	–	–	–	354
b. Transportation	**33 300**	**4**	**70**	**4**	**1 000**	**–**	**–**	**–**	**35 000**
Domestic Aviation	1 420	0.08	2	0.1	40	–	–	–	1 500
Road Transportation	28 200	2.1	44	3.2	980	–	–	–	29 200
Light-Duty Gasoline Vehicles	12 500	0.89	19	1.6	490	–	–	–	13 000
Light-Duty Gasoline Trucks	6 320	0.64	13	1.2	370	–	–	–	6 710
Heavy-Duty Gasoline Vehicles	595	0.08	1.8	0.09	27	–	–	–	624
Motorcycles	63.6	0.05	1.1	0.00	0.38	–	–	–	65.0
Light-Duty Diesel Vehicles	234.0	0.01	0.1	0.02	5	–	–	–	239
Light-Duty Diesel Trucks	82.7	0.00	0.05	0.01	2	–	–	–	84.6
Heavy-Duty Diesel Vehicles	8 360	0.4	9	0.2	80	–	–	–	8 450
Propane & Natural Gas Vehicles	31.2	0.04	0.8	0.00	0.2	–	–	–	32
Railways	672	0.04	0.8	0.3	80	–	–	–	800
Domestic Marine	983	0.1	2	0.1	20	–	–	–	1 000
Others	2 000	1	30	0.4	100	–	–	–	2 000
Off-Road Gasoline	700	0.8	20	0.02	5	–	–	–	800
Off-Road Diesel	970	0.05	1	0.4	100	–	–	–	1 000
Pipelines	347	0.35	7.30	0.01	3	–	–	–	357.0
c. Fugitive Sources	**0.11**	**21**	**450**	**–**	**–**	**–**	**–**	**–**	**450**
Coal Mining	–	–	–	–	–	–	–	–	–
Oil and Natural Gas	0.11	21	450	–	–	–	–	–	450
INDUSTRIAL PROCESSES	**7 080**	**–**	**–**	**0.05**	**15.0**	**–**	**1 950**	**1 210**	**10 300**
a. Mineral Production[1]	**1 700**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**1 700**
Cement	1 200	–	–	–	–	–	–	–	1 200
Lime	500	–	–	–	–	–	–	–	500
b. Chemical Industry[2]	**–**	**–**	**–**	**0.05**	**15.0**	**–**	**–**	**–**	**15**
Nitric Acid Production	–	–	–	0.05	15	–	–	–	15
Adipic Acid Production	–	–	–	–	–	–	–	–	–
c. Metal Production	**4 200**	**–**	**–**	**–**	**–**	**–**	**1 950**	**1 210**	**7 310**
Iron and Steel Production	8.29	–	–	–	–	–	–	–	8.29
Aluminium Production	4 100	–	–	–	–	–	1 950	–	6 090
SF_6 Used in Magnesium Smelters and Casters[3]	–	–	–	–	–	–	–	1 210	1 210
d. Consumption of Halocarbons and SF_6[1]	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
e. Other & Undifferentiated Production[2]	**1 300**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**1 300**
SOLVENT & OTHER PRODUCT USE	**–**	**–**	**–**	**0.36**	**110**	**–**	**–**	**–**	**110**
AGRICULTURE	**–**	**165**	**3 460**	**12**	**3 700**	**–**	**–**	**–**	**7 200**
a. Enteric Fermentation	**–**	**119**	**2 490**	**–**	**–**	**–**	**–**	**–**	**2 490**
b. Manure Management	**–**	**46**	**980**	**1.8**	**560**	**–**	**–**	**–**	**1 500**
c. Agricultural Soils	**–**	**–**	**–**	**10**	**3 100**	**–**	**–**	**–**	**3 100**
Direct Sources	–	–	–	8.0	2 500	–	–	–	2 500
Indirect Sources	–	–	–	2	700	–	–	–	700
WASTE	**120**	**290**	**6 000**	**0.8**	**300**	**–**	**–**	**–**	**6 400**
a. Solid Waste Disposal on Land	**–**	**290**	**6 000**	**–**	**–**	**–**	**–**	**–**	**6 000**
b. Wastewater Handling	**–**	**1.6**	**34**	**0.8**	**200**	**–**	**–**	**–**	**270**
c. Waste Incineration	**120**	**0.1**	**3**	**0.08**	**30**	**–**	**–**	**–**	**150**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

3 Only SF_6 emissions from magnesium smelters are included. Information on SF_6 use in casters is confidential for this province.

Totals may not add due to rounding.

TABLE A12-12: 1990–2003 Greenhouse Gas Emissions Summary for Ontario

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	kt CO$_2$ eq													
TOTAL	**178 000**	**178 000**	**181 000**	**173 000**	**175 000**	**178 000**	**186 000**	**191 000**	**191 000**	**195 000**	**205 000**	**196 000**	**202 000**	**206 000**
ENERGY	**134 000**	**132 000**	**136 000**	**129 000**	**129 000**	**132 000**	**139 000**	**146 000**	**149 000**	**157 000**	**167 000**	**161 000**	**165 000**	**169 000**
a. Stationary Combustion Sources	**84 500**	**84 200**	**86 000**	**77 400**	**76 400**	**77 700**	**83 400**	**88 000**	**90 100**	**94 700**	**104 000**	**100 000**	**103 000**	**107 000**
Electricity and Heat Generation	26 600	27 900	27 600	18 500	16 200	19 100	20 900	26 000	33 700	35 800	42 800	40 700	40 600	41 300
Fossil Fuel Industries	6 700	6 000	6 500	6 700	6 200	6 000	6 400	6 400	6 400	6 400	6 400	6 400	6 400	8 100
Mining	501	675	811	553	651	678	680	658	528	459	469	405	413	409
Manufacturing Industries	22 800	21 500	21 100	20 700	21 900	21 200	21 600	22 000	21 100	21 300	20 900	19 600	20 600	20 500
Construction	573	527	559	337	421	373	444	492	451	477	439	391	522	549
Commercial & Institutional	9 170	9 670	10 200	10 200	9 930	9 860	10 900	11 400	10 300	11 500	13 200	13 600	12 900	14 000
Residential	17 000	17 000	18 000	19 000	20 000	19 000	21 000	21 000	21 000	21 000	21 000	21 000	21 000	21 000
Agriculture & Forestry	781	894	1 110	997	940	1 150	1 130	1 050	936	959	902	761	834	984
b. Transportation	**48 000**	**47 000**	**48 000**	**50 000**	**51 000**	**53 000**	**54 000**	**54 000**	**54 000**	**54 000**	**54 000**	**54 000**	**54 000**	**61 000**
Domestic Aviation	1 600	1 400	1 200	1 200	1 200	1 300	1 400	1 400	1 400	1 400	1 400	1 400	1 400	1 500
Road Transportation	37 900	36 800	38 000	39 500	40 600	41 800	42 400	44 400	44 000	46 400	47 300	49 300	50 600	52 200
Light-Duty Gasoline Vehicles	21 000	20 200	20 200	20 300	20 500	20 000	19 500	19 800	19 200	19 400	19 000	20 000	20 200	20 100
Light-Duty Gasoline Trucks	7 690	7 960	8 480	9 120	9 740	10 100	10 700	11 600	11 700	13 400	14 000	15 100	15 800	16 500
Heavy-Duty Gasoline Vehicles	887	922	983	1 050	1 120	1 160	1 200	1 220	1 270	1 010	1 030	1 000	1 020	992
Motorcycles	85.1	81.5	80.3	80.7	77.8	72.7	68.5	70.8	71.5	68.4	69.9	68.9	66.6	64.7
Light-Duty Diesel Vehicles	211	200	195	191	186	176	183	185	183	190	197	220	238	259
Light-Duty Diesel Trucks	163	124	110	101	92.1	85.9	72.1	89.5	66.9	108	118	132	145	155
Heavy-Duty Diesel Vehicles	7 350	6 610	6 920	7 580	8 270	9 390	9 770	10 700	10 800	11 600	12 500	12 400	12 900	13 800
Propane & Natural Gas Vehicles	540	660	1 100	1 000	590	800	830	830	830	830	830	830	830	290
Railways	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	1 000
Domestic Marine	940	940	890	690	710	660	710	710	710	710	710	710	710	580
Others	6 000	6 000	6 000	6 000	7 000	7 000	8 000	8 000	8 000	8 000	8 000	8 000	8 000	6 000
Off-Road Gasoline	1 000	1 000	900	800	800	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	600
Off-Road Diesel	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Pipelines	2 270	2 400	3 250	3 410	3 460	4 050	4 360	4 240	4 060	4 110	3 630	2 520	3 080	2 510
c. Fugitive Sources	**1 360**	**1 400**	**1 440**	**1 450**	**1 480**	**1 500**	**1 510**	**1 530**	**1 560**	**1 630**	**1 720**	**1 800**	**1 800**	**1 790**
Coal Mining	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oil and Natural Gas	1 360	1 400	1 440	1 450	1 480	1 500	1 510	1 530	1 560	1 630	1 720	1 800	1 800	1 790
INDUSTRIAL PROCESSES	**26 100**	**26 600**	**26 800**	**25 300**	**26 900**	**27 500**	**28 400**	**26 600**	**22 300**	**19 200**	**18 600**	**16 800**	**17 900**	**17 300**
a. Mineral Production[1]	**3 400**	**3 300**	**3 300**	**3 400**	**3 700**	**3 800**	**4 000**	**4 000**	**4 000**	**4 000**	**4 000**	**4 000**	**4 000**	**4 000**
Cement	2 300	2 200	2 200	2 300	2 600	2 700	2 900	2 900	2 900	2 900	2 900	2 900	2 900	3 300
Lime	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	800
b. Chemical Industry[2]	**11 000**	**10 000**	**10 000**	**9 200**	**11 000**	**11 000**	**12 000**	**12 000**	**12 000**	**12 000**	**12 000**	**12 000**	**12 000**	**1 200**
Nitric Acid Production	83	78	82	83	78	85	79	79	79	79	79	79	79	84
Adipic Acid Production	10 700	10 000	9 950	9 080	11 000	10 700	11 500	9 890	5 070	1 750	900	802	1 250	1 090
c. Metal Production	**7 780**	**9 120**	**9 200**	**8 840**	**8 230**	**8 590**	**8 460**	**8 400**	**8 660**	**9 190**	**9 450**	**8 270**	**8 450**	**8 280**
Iron and Steel Production	7 060	8 310	8 490	8 160	7 520	7 850	7 730	7 540	7 670	7 880	7 880	7 270	7 100	7 030
Aluminium Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SF$_6$ Used in Magnesium Smelters and Casters	720	809	712	672	711	734	731	858	989	1 320	1 570	999	1 340	1 240
d. Consumption of Halocarbons and SF$_6$[1]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**4 100**	**4 100**	**4 200**	**3 900**	**3 900**	**4 300**	**4 500**	**4 500**	**4 500**	**4 500**	**4 500**	**4 500**	**4 500**	**3 800**
SOLVENT & OTHER PRODUCT USE	**160**	**160**	**160**	**160**	**160**	**160**	**170**	**170**	**170**	**170**	**170**	**170**	**170**	**180**
AGRICULTURE	**11 000**	**11 000**	**10 000**	**10 000**	**11 000**	**11 000**	**10 000**	**10 000**	**10 000**	**10 000**	**10 000**	**10 000**	**10 000**	**10 000**
a. Enteric Fermentation	**3 750**	**3 720**	**3 640**	**3 490**	**3 510**	**3 590**	**3 470**	**3 640**	**3 540**	**3 420**	**3 360**	**3 400**	**3 390**	**3 500**
b. Manure Management	**1 700**	**1 700**	**1 700**	**1 600**	**1 600**	**1 700**	**1 700**	**1 700**	**1 700**	**1 700**	**1 700**	**1 700**	**1 700**	**1 700**
c. Agricultural Soils	**5 500**	**5 200**	**5 100**	**5 300**	**5 500**	**5 500**	**5 200**	**5 200**	**5 200**	**5 200**	**5 200**	**5 200**	**5 200**	**5 100**
Direct Sources	4 500	4 300	4 200	4 400	4 500	4 600	4 300	4 300	4 300	4 300	4 300	4 300	4 300	4 200
Indirect Sources	1 000	1 000	900	900	900	900	900	900	900	900	900	900	900	900
WASTE	**7 200**	**7 800**	**8 000**	**8 200**	**8 400**	**8 100**	**7 700**	**7 700**	**7 700**	**7 700**	**7 700**	**7 700**	**7 700**	**9 000**
a. Solid Waste Disposal on Land	**6 700**	**7 400**	**7 600**	**7 800**	**7 900**	**7 600**	**7 200**	**7 200**	**7 200**	**7 200**	**7 200**	**7 200**	**7 200**	**8 400**
b. Wastewater Handling	**380**	**390**	**390**	**400**	**400**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**450**
c. Waste Incineration	**80**	**81**	**82**	**79**	**79**	**81**	**82**	**82**	**82**	**82**	**82**	**82**	**82**	**90**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

Totals may not add due to rounding.

TABLE A12-13: 2003 Greenhouse Gas Emissions Summary for Ontario

GHG Source Category	Greenhouse Gases CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**179 000**	**740**	**15 000**	**35**	**11 000**	**–**	**–**	**1 200**	**206 000**
ENERGY	**164 000**	**100**	**3 000**	**10**	**3 000**	**–**	**–**	**–**	**169 000**
a. Stationary Combustion Sources	**105 000**	**30**	**600**	**2**	**700**	**–**	**–**	**–**	**107 000**
Electricity and Heat Generation	41 100	1.8	39	0.7	200	–	–	–	41 300
Fossil Fuel Industries	8 100	0.1	2	0.06	20	–	–	–	8 100
Mining	405	0.01	0.2	0.01	3	–	–	–	409
Manufacturing Industries	20 300	0.8	20	0.5	200	–	–	–	20 500
Construction	545	0.01	0.2	0.01	3	–	–	–	549
Commercial & Institutional	14 000	0.3	5	0.3	90	–	–	–	14 000
Residential	19 900	20	500	0.6	200	–	–	–	21 000
Agriculture & Forestry	977	0.02	0.4	0.02	7	–	–	–	984
b. Transportation	**58 500**	**8**	**200**	**8**	**2 000**	**–**	**–**	**–**	**61 000**
Domestic Aviation	1 480	0.08	2	0.1	50	–	–	–	1 500
Road Transportation	50 100	5.0	100	6.4	2 000	–	–	–	52 200
Light-Duty Gasoline Vehicles	19 300	1.5	31	2.5	780	–	–	–	20 100
Light-Duty Gasoline Trucks	15 500	1.8	38	3.3	1 000	–	–	–	16 500
Heavy-Duty Gasoline Vehicles	946	0.13	2.8	0.14	44	–	–	–	992
Motorcycles	63.2	0.05	1.1	0.00	0.38	–	–	–	64.7
Light-Duty Diesel Vehicles	253	0.01	0.1	0.02	6	–	–	–	259
Light-Duty Diesel Trucks	151	0.00	0.09	0.01	3	–	–	–	155
Heavy-Duty Diesel Vehicles	13 600	0.7	10	0.4	100	–	–	–	13 800
Propane & Natural Gas Vehicles	269	0.9	20	0.01	2	–	–	–	290
Railways	1 170	0.06	1	0.5	100	–	–	–	1 000
Domestic Marine	553	0.05	1	0.08	20	–	–	–	580
Others	5 100	3	70	0.9	300	–	–	–	6 000
Off-Road Gasoline	500	0.6	10	0.01	4	–	–	–	600
Off-Road Diesel	2 200	0.1	2	0.9	300	–	–	–	2 000
Pipelines	2 440	2.4	51	0.07	20	–	–	–	2 510
c. Fugitive Sources	**9.4**	**85**	**1 800**	**–**	**–**	**–**	**–**	**–**	**1 790**
Coal Mining	–	–	–	–	–	–	–	–	–
Oil and Natural Gas	9.4	85	1 800	–	–	–	–	–	1 790
INDUSTRIAL PROCESSES	**14 900**	**–**	**–**	**3.77**	**1 170**	**–**	**–**	**1 240**	**17 300**
a. Mineral Production[1]	**4 000**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**4 000**
Cement	3 300	–	–	–	–	–	–	–	3 300
Lime	800	–	–	–	–	–	–	–	800
b. Chemical Industry[2]	**–**	**–**	**–**	**3.77**	**1 170**	**–**	**–**	**–**	**1 200**
Nitric Acid Production	–	–	–	0.27	84	–	–	–	84
Adipic Acid Production	–	–	–	3.50	1 090	–	–	–	1 090
c. Metal Production	**7 000**	**–**	**–**	**–**	**–**	**–**	**–**	**1 240**	**8 280**
Iron and Steel Production	7 030	–	–	–	–	–	–	–	7 030
Aluminium Production	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	1 240	1 240
d. Consumption of Halocarbons and SF_6[1]	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
e. Other & Undifferentiated Production[2]	**3 800**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**3 800**
SOLVENT & OTHER PRODUCT USE	**–**	**–**	**–**	**0.59**	**180**	**–**	**–**	**–**	**180**
AGRICULTURE	**–**	**211**	**4 430**	**19**	**5 900**	**–**	**–**	**–**	**10 000**
a. Enteric Fermentation	**–**	**167**	**3 500**	**–**	**–**	**–**	**–**	**–**	**3 500**
b. Manure Management	**–**	**44**	**930**	**2.6**	**790**	**–**	**–**	**–**	**1 700**
c. Agricultural Soils	**–**	**–**	**–**	**16**	**5 100**	**–**	**–**	**–**	**5 100**
Direct Sources	–	–	–	14	4 200	–	–	–	4 200
Indirect Sources	–	–	–	3	900	–	–	–	900
WASTE	**71**	**400**	**8 500**	**1**	**400**	**–**	**–**	**–**	**9 000**
a. Solid Waste Disposal on Land	**–**	**400**	**8 400**	**–**	**–**	**–**	**–**	**–**	**8 400**
b. Wastewater Handling	**–**	**3.4**	**71**	**1**	**400**	**–**	**–**	**–**	**450**
c. Waste Incineration	**71**	**0.2**	**4**	**0.05**	**10**	**–**	**–**	**–**	**90**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

Totals may not add due to rounding.

TABLE A12-14: 1990–2003 Greenhouse Gas Emissions Summary for Manitoba

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	kt CO_2 eq													
TOTAL	**19 100**	**18 800**	**19 000**	**18 900**	**19 600**	**20 400**	**21 300**	**20 500**	**21 000**	**20 800**	**21 500**	**20 000**	**20 700**	**21 300**
ENERGY	**12 400**	**12 000**	**12 000**	**11 900**	**12 100**	**12 700**	**13 100**	**12 500**	**12 700**	**12 600**	**13 100**	**11 900**	**12 400**	**12 500**
a. Stationary Combustion Sources	**4 850**	**4 520**	**4 290**	**4 170**	**4 080**	**4 210**	**4 620**	**4 300**	**4 840**	**4 600**	**5 350**	**4 570**	**4 910**	**4 950**
Electricity and Heat Generation	570	418	417	284	323	219	340	244	962	546	993	X	X	X
Fossil Fuel Industries	3.6	1.1	1.7	1.2	1.2	1.5	1.3	0.92	0.61	0.91	1.0	1.0	17	0.47
Mining	73.1	75.7	57.6	27.8	8.12	12.5	10.5	12.1	33.9	27.4	29.4	X	X	X
Manufacturing Industries	1 050	953	766	703	777	821	840	808	914	1 080	1 140	1 060	1 210	1 160
Construction	63.1	45.4	50.5	38.2	40.8	33.8	31.9	45.0	84.8	76.0	62.2	61.4	68.6	78.8
Commercial & Institutional	1 410	1 430	1 480	1 530	1 430	1 590	1 670	1 650	1 490	1 470	1 680	1 590	1 710	1 580
Residential	1 600	1 600	1 500	1 500	1 400	1 500	1 600	1 400	1 300	1 300	1 400	1 200	1 300	1 300
Agriculture & Forestry	42.9	47.3	52.0	101	77.4	76.7	110	98.3	71.6	86.5	62.8	X	X	X
b. Transportation	**7 200**	**7 000**	**7 200**	**7 300**	**7 500**	**8 000**	**8 000**	**7 700**	**7 300**	**7 500**	**7 200**	**6 800**	**6 900**	**7 000**
Domestic Aviation	330	300	280	280	340	370	380	390	330	360	360	350	360	390
Road Transportation	4 160	4 220	4 260	4 220	4 410	4 550	4 560	4 540	4 570	4 680	4 590	4 610	4 710	4 770
Light-Duty Gasoline Vehicles	1 990	1 970	1 910	1 810	1 790	1 750	1 660	1 540	1 540	1 510	1 440	1 430	1 440	1 440
Light-Duty Gasoline Trucks	867	932	982	1 010	1 080	1 130	1 230	1 250	1 300	1 420	1 440	1 450	1 510	1 540
Heavy-Duty Gasoline Vehicles	194	211	224	231	246	258	204	255	250	227	238	236	236	237
Motorcycles	7.31	7.61	7.28	6.69	6.52	6.29	3.75	5.05	4.98	3.92	3.54	2.89	2.76	2.35
Light-Duty Diesel Vehicles	20.3	20.1	19.3	18.0	17.5	16.6	16.8	15.5	15.5	15.3	14.7	15.0	15.7	16.3
Light-Duty Diesel Trucks	30.9	30.0	30.6	31.7	33.4	35.4	37.2	30.3	28.4	31.7	34.5	32.2	35.9	37.7
Heavy-Duty Diesel Vehicles	992	989	1 030	1 090	1 160	1 250	1 330	1 320	1 320	1 350	1 380	1 400	1 450	1 470
Propane & Natural Gas Vehicles	61	64	60	27	71	97	83	120	110	110	36	31	20	22
Railways	600	500	500	500	600	600	500	400	400	300	300	200	90	200
Domestic Marine	-	-	0.30	-	-	-	-	-	-	-	-	-	-	0.29
Others	2 000	2 000	2 000	2 000	2 000	3 000	3 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Off-Road Gasoline	300	300	400	400	400	500	400	400	400	400	400	400	400	400
Off-Road Diesel	900	700	600	600	600	800	800	700	700	600	700	700	700	800
Pipelines	847	976	1 220	1 260	1 200	1 300	1 300	1 200	959	1 060	828	543	658	450
c. Fugitive Sources	**415**	**420**	**433**	**440**	**443**	**458**	**487**	**502**	**510**	**509**	**533**	**537**	**537**	**536**
Coal Mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil and Natural Gas	415	420	433	440	443	458	487	502	510	509	533	537	537	536
INDUSTRIAL PROCESSES	**470**	**403**	**294**	**299**	**296**	**294**	**299**	**305**	**309**	**441**	**469**	**200**	**271**	**267**
a. Mineral Production^1	**210**	**170**	**60**	**65**	**67**	**69**	**67**	**70**	**70**	**64**	**69**	**61**	**63**	**57**
Cement	150	110	-	-	-	-	-	-	-	-	-	-	-	-
Lime	60	60	60	60	70	70	70	70	70	60	70	60	60	60
b. Chemical Industry^2	**21**	**20**	**21**	**21**	**24**	**27**	**30**	**29**	**27**	**29**	**31**	**30**	**33**	**32**
Nitric Acid Production	21	20	21	21	24	27	30	29	27	29	31	30	33	32
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iron and Steel Production	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminium Production	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SF_6 Used in Magnesium Smelters and Casters	-	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons and SF_6^{1}	-	-	-	-	-	-	-	-	-	-	-	-	-	-
e. Other & Undifferentiated Production^2	**240**	**220**	**210**	**210**	**210**	**200**	**200**	**210**	**210**	**350**	**370**	**110**	**180**	**180**
SOLVENT & OTHER PRODUCT USE	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**18**
AGRICULTURE	**5 700**	**5 900**	**6 200**	**6 200**	**6 700**	**6 900**	**7 300**	**7 100**	**7 400**	**7 200**	**7 300**	**7 200**	**7 500**	**7 900**
a. Enteric Fermentation	**1 540**	**1 560**	**1 660**	**1 740**	**1 880**	**2 000**	**2 090**	**2 050**	**2 040**	**1 980**	**1 970**	**2 030**	**2 100**	**2 200**
b. Manure Management	**540**	**550**	**590**	**600**	**650**	**700**	**740**	**720**	**740**	**710**	**710**	**810**	**860**	**880**
c. Agricultural Soils	**3 700**	**3 800**	**4 000**	**3 900**	**4 100**	**4 200**	**4 500**	**4 300**	**4 600**	**4 500**	**4 600**	**4 400**	**4 500**	**4 800**
Direct Sources	2 900	3 000	3 100	3 000	3 200	3 200	3 500	3 300	3 600	3 500	3 600	3 400	3 500	3 800
Indirect Sources	700	800	800	900	900	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000
WASTE	**420**	**470**	**490**	**500**	**520**	**530**	**550**	**560**	**580**	**590**	**610**	**620**	**630**	**650**
a. Solid Waste Disposal on Land	**370**	**420**	**430**	**450**	**460**	**470**	**490**	**500**	**520**	**530**	**550**	**560**	**570**	**590**
b. Wastewater Handling	**57**	**57**	**57**	**57**	**58**	**58**	**58**	**58**	**58**	**59**	**59**	**59**	**59**	**60**
c. Waste Incineration	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-15: 2003 Greenhouse Gas Emissions Summary for Manitoba

	Greenhouse Gases								
GHG Source Category	**CO_2**	**CH_4**	**CH_4**	**N_2O**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**TOTAL**
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**11 800**	**190**	**3 900**	**18**	**5 700**	–	–	–	**21 300**
ENERGY	**11 500**	**30**	**600**	**1**	**300**	–	–	–	**12 500**
a. Stationary Combustion Sources	**4 860**	**3**	**50**	**0.1**	**40**	–	–	–	**4 950**
Electricity and Heat Generation	X	X	X	X	X	–	–	–	X
Fossil Fuel Industries	0.46	0.00	0.00	0.00	0.01	–	–	–	0.47
Mining	X	X	X	X	X	–	–	–	X
Manufacturing Industries	1 160	0.04	0.9	0.03	8	–	–	–	1 160
Construction	78.3	0.00	0.03	0.00	0.5	–	–	–	78.8
Commercial & Institutional	1 570	0.03	0.6	0.03	10	–	–	–	1 580
Residential	1 190	2	50	0.05	20	–	–	–	1 300
Agriculture & Forestry	X	X	X	X	X	–	–	–	X
b. Transportation	**6 680**	**1**	**30**	**1**	**300**	–	–	–	**7 000**
Domestic Aviation	382	0.04	0.8	0.04	10	–	–	–	390
Road Transportation	4 580	0.42	8.8	0.58	180	–	–	–	4 770
Light-Duty Gasoline Vehicles	1 380	0.12	2.6	0.19	58	–	–	–	1 440
Light-Duty Gasoline Trucks	1 440	0.16	3.4	0.31	95	–	–	–	1 540
Heavy-Duty Gasoline Vehicles	226	0.03	0.67	0.03	10	–	–	–	237
Motorcycles	2.30	0.00	0.04	0.00	0.01	–	–	–	2.35
Light-Duty Diesel Vehicles	15.9	0.00	0.01	0.00	0.4	–	–	–	16.3
Light-Duty Diesel Trucks	36.8	0.00	0.02	0.00	0.8	–	–	–	37.7
Heavy-Duty Diesel Vehicles	1 460	0.07	2	0.04	10	–	–	–	1 470
Propane & Natural Gas Vehicles	20.9	0.03	0.6	0.00	0.1	–	–	–	22
Railways	167	0.01	0.2	0.07	20	–	–	–	200
Domestic Marine	0.26	0.00	0.00	0.00	0.03	–	–	–	0.29
Others	1 500	0.9	20	0.3	100	–	–	–	2 000
Off-Road Gasoline	400	0.4	9	0.01	3	–	–	–	400
Off-Road Diesel	720	0.04	0.8	0.3	90	–	–	–	800
Pipelines	437	0.44	9.2	0.01	4	–	–	–	450
c. Fugitive Sources	**0.59**	**25**	**540**	–	–	–	–	–	**536**
Coal Mining	–	–	–	–	–	–	–	–	–
Oil and Natural Gas	0.59	25	540	–	–	–	–	–	536
INDUSTRIAL PROCESSES	**235**	–	–	**0.10**	**31.7**	–	–	–	**267**
a. Mineral Production[1]	**57**	–	–	–	–	–	–	–	**57**
Cement	–	–	–	–	–	–	–	–	–
Lime	60	–	–	–	–	–	–	–	60
b. Chemical Industry[2]	–	–	–	**0.10**	**31.7**	–	–	–	**32**
Nitric Acid Production	–	–	–	0.10	32	–	–	–	32
Adipic Acid Production	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**180**	–	–	–	–	–	–	–	**180**
SOLVENT & OTHER PRODUCT USE	–	–	–	0.06	**18**	–	–	–	**18**
AGRICULTURE	–	**128**	**2 690**	**17**	**5 200**	–	–	–	**7 900**
a. Enteric Fermentation	–	**105**	**2 200**	–	–	–	–	–	**2 200**
b. Manure Management	–	**24**	**490**	**1.20**	**380**	–	–	–	**880**
c. Agricultural Soils	–	–	–	**16**	**4 800**	–	–	–	**4 800**
Direct Sources	–	–	–	12	3 800	–	–	–	3 800
Indirect Sources	–	–	–	3	1 000	–	–	–	1 000
WASTE	–	**29**	**610**	**0.1**	**40**	–	–	–	**650**
a. Solid Waste Disposal on Land	–	**28**	**590**	–	–	–	–	–	**590**
b. Wastewater Handling	–	**1.1**	**23**	**0.1**	**40**	–	–	–	**60**
c. Waste Incineration	–	–	–	–	–	–	–	–	–

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-16: 1990–2003 Greenhouse Gas Emissions Summary for Saskatchewan

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	kt CO_2 eq													
TOTAL	**45 000**	**44 700**	**49 500**	**52 800**	**57 000**	**59 400**	**61 600**	**62 900**	**63 500**	**63 500**	**64 200**	**62 500**	**62 500**	**65 200**
ENERGY	**34 500**	**34 100**	**38 100**	**40 500**	**44 000**	**46 000**	**46 000**	**46 800**	**47 400**	**47 700**	**47 800**	**47 200**	**48 500**	**48 900**
a. Stationary Combustion Sources	**18 900**	**18 100**	**21 100**	**22 600**	**25 000**	**25 800**	**24 700**	**25 300**	**26 300**	**26 200**	**26 000**	**26 500**	**27 300**	**27 400**
Electricity and Heat Generation	10 400	10 600	12 100	12 400	13 300	13 900	14 000	14 900	15 100	14 900	14 700	X	X	X
Fossil Fuel Industries	3 200	1 600	2 400	3 300	4 600	5 100	3 400	3 800	4 700	4 700	4 400	4 700	5 100	4 200
Mining	965	978	969	1 700	1 810	1 690	1 320	1 900	1 810	1 660	2 000	X	X	X
Manufacturing Industries	856	1 430	2 270	1 170	1 530	1 300	1 570	1 060	1 120	967	934	792	713	694
Construction	70.3	56.7	80.3	71.2	65.4	73.0	87.1	56.1	65.3	86.8	49.6	40.7	39.0	37.4
Commercial & Institutional	1 010	1 010	926	1 480	1 310	1 210	1 420	1 200	1 250	1 590	1 710	1 590	2 030	1 970
Residential	2 100	2 200	2 100	2 100	2 100	2 100	2 500	2 100	1 900	2 000	2 000	2 000	2 000	1 800
Agriculture & Forestry	302	274	303	333	327	328	387	349	292	339	281	X	X	X
b. Transportation	**9 500**	**9 600**	**10 000**	**11 000**	**11 000**	**11 000**	**12 000**	**12 000**	**11 000**	**12 000**	**11 000**	**9 900**	**10 000**	**10 000**
Domestic Aviation	210	180	180	160	150	170	170	150	170	140	110	120	130	120
Road Transportation	4 380	4 750	5 430	5 410	5 610	5 490	5 810	6 580	5 960	6 190	6 140	5 420	6 000	6 330
Light-Duty Gasoline Vehicles	1 590	1 600	1 900	1 770	1 640	1 480	1 450	1 500	1 370	1 370	1 280	1 040	1 240	1 300
Light-Duty Gasoline Trucks	1 030	1 100	1 400	1 400	1 410	1 400	1 560	1 680	1 500	1 750	1 730	1 400	1 740	1 850
Heavy-Duty Gasoline Vehicles	193	242	355	406	460	507	517	595	590	480	479	363	444	470
Motorcycles	1.88	2.01	2.56	2.61	3.03	3.03	2.75	5.77	5.62	6.37	6.79	6.44	6.84	7.58
Light-Duty Diesel Vehicles	14.3	14.3	16.7	15.1	13.3	11.2	13.2	13.2	12.5	13.0	12.6	11.0	14.2	16.1
Light-Duty Diesel Trucks	75.7	86.6	83.5	86.3	99.4	99.1	108	122	110	102	120	120	126	126
Heavy-Duty Diesel Vehicles	1 410	1 640	1 600	1 660	1 930	1 940	2 120	2 610	2 310	2 420	2 480	2 450	2 400	2 550
Propane & Natural Gas Vehicles	65	64	80	62	52	50	44	59	59	48	27	31	19	13
Railways	600	300	400	400	500	500	600	600	500	400	400	300	300	200
Domestic Marine	–	–	–	–	–	–	–	–	–	–	0.02	0.04	0.01	0.01
Others	4 000	4 000	4 000	5 000	5 000	5 000	5 000	4 000	5 000	5 000	4 000	4 000	4 000	4 000
Off-Road Gasoline	1 000	1 000	400	600	800	800	800	400	700	600	700	1 000	800	800
Off-Road Diesel	1 000	1 000	1 000	2 000	2 000	2 000	2 000	2 000	1 000	1 000	1 000	1 000	1 000	1 000
Pipelines	1 640	1 780	2 430	2 460	2 270	2 600	2 570	2 500	2 660	2 790	2 410	1 720	2 000	1 590
c. Fugitive Sources	**6 140**	**6 350**	**6 750**	**7 390**	**7 880**	**8 770**	**9 570**	**9 800**	**9 810**	**10 000**	**10 600**	**10 900**	**10 800**	**11 100**
Coal Mining	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Oil and Natural Gas	6 130	6 340	6 730	7 370	7 870	8 760	9 560	9 780	9 790	9 990	10 600	10 800	10 800	11 100
INDUSTRIAL PROCESSES	**591**	**671**	**690**	**1 180**	**987**	**797**	**1 670**	**1 790**	**2 030**	**1 660**	**1 620**	**1 380**	**1 270**	**1 410**
a. Mineral Production[1]	**85**	**66**	–	–	–	–	–	–	–	–	–	–	–	–
Cement	85	66	–	–	–	–	–	–	–	–	–	–	–	–
Lime	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**510**	**600**	**690**	**1 200**	**990**	**800**	**1 700**	**1 800**	**2 000**	**1 700**	**1 600**	**1 400**	**1 300**	**1 400**
SOLVENT & OTHER PRODUCT USE	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**
AGRICULTURE	**9 400**	**9 400**	**10 000**	**11 000**	**11 000**	**12 000**	**13 000**	**14 000**	**13 000**	**14 000**	**14 000**	**13 000**	**12 000**	**14 000**
a. Enteric Fermentation	**2 940**	**3 020**	**3 220**	**3 320**	**3 500**	**3 710**	**3 810**	**3 930**	**3 780**	**3 670**	**3 610**	**3 900**	**3 920**	**4 300**
b. Manure Management	**710**	**730**	**780**	**800**	**840**	**870**	**890**	**910**	**890**	**870**	**870**	**930**	**940**	**1 000**
c. Agricultural Soils	**5 700**	**5 600**	**6 100**	**6 400**	**7 100**	**7 500**	**8 600**	**8 900**	**8 800**	**9 000**	**9 600**	**8 500**	**7 200**	**8 900**
Direct Sources	4 800	4 800	5 100	5 300	5 800	6 100	7 000	7 100	7 200	7 400	8 000	6 800	5 700	7 100
Indirect Sources	900	900	1 000	1 000	1 000	1 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
WASTE	**500**	**520**	**530**	**550**	**560**	**570**	**580**	**590**	**600**	**610**	**620**	**630**	**640**	**650**
a. Solid Waste Disposal on Land	**420**	**430**	**450**	**460**	**470**	**480**	**490**	**500**	**510**	**520**	**530**	**540**	**550**	**560**
b. Wastewater Handling	**87**	**87**	**87**	**87**	**87**	**88**	**88**	**88**	**88**	**88**	**87**	**87**	**86**	**86**
c. Waste Incineration	**0.06**	**0.06**	**0.06**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-17: 2003 Greenhouse Gas Emissions Summary for Saskatchewan

	Greenhouse Gases								
GHG Source Category	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**40 300**	**700**	**15 000**	**33**	**10 000**	–	–	–	**65 200**
ENERGY	**38 900**	**400**	**9 000**	**2**	**600**	–	–	–	**48 900**
a. Stationary Combustion Sources	**26 900**	**10**	**300**	**0.7**	**200**	–	–	–	**27 400**
Electricity and Heat Generation	X	X	X	X	X	–	–	–	X
Fossil Fuel Industries	4 000	10	200	0.1	40	–	–	–	4 200
Mining	X	X	X	X	X	–	–	–	X
Manufacturing Industries	685	0.06	1	0.03	9	–	–	–	694
Construction	37.1	0.00	0.01	0.00	0.3	–	–	–	37.4
Commercial & Institutional	1 960	0.04	0.8	0.04	10	–	–	–	1 970
Residential	1 750	1	30	0.05	10	–	–	–	1 800
Agriculture & Forestry	X	X	X	X	X	–	–	–	X
b. Transportation	**9 990**	**3**	**60**	**1**	**400**	–	–	–	**10 000**
Domestic Aviation	117	0.02	0.3	0.01	4	–	–	–	120
Road Transportation	6 100	0.57	12	0.70	220	–	–	–	6 330
Light-Duty Gasoline Vehicles	1 240	0.13	2.7	0.16	50	–	–	–	1 300
Light-Duty Gasoline Trucks	1 720	0.22	4.6	0.39	120	–	–	–	1 850
Heavy-Duty Gasoline Vehicles	448	0.06	1.30	0.07	21	–	–	–	470
Motorcycles	7.41	0.01	0.12	0.00	0.05	–	–	–	7.58
Light-Duty Diesel Vehicles	15.7	0.00	0.01	0.00	0.4	–	–	–	16.1
Light-Duty Diesel Trucks	123	0.00	0.07	0.01	3	–	–	–	126.0
Heavy-Duty Diesel Vehicles	2 530	0.1	3	0.07	20	–	–	–	2 550
Propane & Natural Gas Vehicles	12.7	0.03	0.5	0.00	0.08	–	–	–	13
Railways	173	0.01	0.2	0.07	20	–	–	–	200
Domestic Marine	0.01	0.00	0.00	0.00	0.00	–	–	–	0.01
Others	3 600	2	50	0.6	200	–	–	–	4 000
Off-Road Gasoline	700	0.8	20	0.02	5	–	–	–	800
Off-Road Diesel	1 300	0.07	1	0.5	200	–	–	–	1 000
Pipelines	1 550	1.6	33	0.04	10	–	–	–	1 590
c. Fugitive Sources	**2 000**	**430**	**9 100**	–	–	–	–	–	**11 100**
Coal Mining	–	0.7	10	–	–	–	–	–	10
Oil and Natural Gas	2 000	430	9 100	–	–	–	–	–	11 100
INDUSTRIAL PROCESSES	**1 410**	–	–	–	–	–	–	–	**1 410**
a. Mineral Production[1]	–	–	–	–	–	–	–	–	–
Cement	–	–	–	–	–	–	–	–	–
Lime	–	–	–	–	–	–	–	–	–
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	1 400	–	–	–	–	–	–	–	1 400
SOLVENT & OTHER PRODUCT USE	–	–	–	0.05	15	–	–	–	15
AGRICULTURE	–	**222**	**4 660**	**31**	**9 500**	–	–	–	**14 000**
a. Enteric Fermentation	–	**205**	**4 300**	–	–	–	–	–	**4 300**
b. Manure Management	–	**17**	**350**	**2.2**	**670**	–	–	–	**1 000**
c. Agricultural Soils	–	–	–	**29**	**8 900**	–	–	–	**8 900**
Direct Sources	–	–	–	23	7 100	–	–	–	7 100
Indirect Sources	–	–	–	6	2 000	–	–	–	2 000
WASTE	–	**29**	**620**	**0.1**	**30**	–	–	–	**650**
a. Solid Waste Disposal on Land	–	**27**	**560**	–	–	–	–	–	**560**
b. Wastewater Handling	–	**2.6**	**55**	**0.1**	**30**	–	–	–	**86**
c. Waste Incineration	–	**0.00**	**0.00**	–	–	–	–	–	**0.00**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

X Denotes confidential values.

Totals may not add due to rounding.

TABLE A12-18: 1990–2003 Greenhouse Gas Emissions Summary for Alberta

kt CO_2 eq

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
TOTAL	**168 000**	**170 000**	**178 000**	**183 000**	**192 000**	**197 000**	**201 000**	**203 000**	**204 000**	**213 000**	**221 000**	**219 000**	**218 000**	**224 000**
ENERGY	**143 000**	**145 000**	**152 000**	**156 000**	**163 000**	**168 000**	**171 000**	**173 000**	**174 000**	**181 000**	**190 000**	**190 000**	**191 000**	**196 000**
a. Stationary Combustion Sources	**95 200**	**97 800**	**103 000**	**104 000**	**108 000**	**111 000**	**111 000**	**110 000**	**111 000**	**118 000**	**126 000**	**124 000**	**127 000**	**132 000**
Electricity and Heat Generation	40 200	42 100	45 300	46 000	49 600	49 200	48 400	51 200	51 800	50 100	52 100	53 500	53 000	54 900
Fossil Fuel Industries	31 000	33 000	35 000	35 000	35 000	35 000	34 000	31 000	33 000	42 000	44 000	45 000	45 000	43 000
Mining	2 400	1 430	1 200	3 200	2 880	3 340	4 280	3 920	3 450	3 450	5 500	5 890	7 520	11 000
Manufacturing Industries	9 410	9 600	9 370	8 270	8 920	9 950	9 940	10 500	10 000	9 670	9 610	7 890	7 760	7 830
Construction	236	202	244	212	206	189	216	211	136	166	172	168	170	158
Commercial & Institutional	4 950	4 760	4 410	4 540	4 570	5 520	4 970	5 020	4 640	4 580	5 290	4 750	5 720	6 070
Residential	6 600	6 600	6 400	6 600	7 300	7 600	8 700	7 700	7 400	7 500	8 300	7 200	8 000	8 200
Agriculture & Forestry	468	458	560	574	358	335	410	380	341	348	361	286	301	270
b. Transportation	**23 000**	**21 000**	**21 000**	**22 000**	**24 000**	**25 000**	**26 000**	**29 000**	**30 000**	**30 000**	**30 000**	**32 000**	**31 000**	**32 000**
Domestic Aviation	1 100	920	980	1 000	1 000	1 000	1 100	1 200	1 300	1 300	1 300	1 400	1 400	1 300
Road Transportation	14 400	13 600	13 900	13 900	15 800	16 000	16 100	17 500	17 900	18 100	18 800	19 700	19 600	19 900
Light-Duty Gasoline Vehicles	5 620	5 140	5 070	4 940	5 200	5 040	4 630	4 780	4 960	4 810	4 690	4 970	4 940	4 620
Light-Duty Gasoline Trucks	3 650	3 520	3 670	3 770	4 180	4 270	4 250	4 690	4 840	5 490	5 610	6 040	6 270	6 160
Heavy-Duty Gasoline Vehicles	650	694	788	871	1 030	1 110	1 100	1 180	1 320	989	1 130	1 070	1 060	1 090
Motorcycles	25.3	24.4	22.8	23.9	25.7	23.5	21.7	23.6	26.6	25.0	25.5	26.1	24.5	24.2
Light-Duty Diesel Vehicles	52.0	46.2	43.9	40.7	40.2	36.2	33.8	36.3	38.1	38.3	36.7	43.1	47.6	52.4
Light-Duty Diesel Trucks	87.1	70.3	61.4	57.5	60.3	54.2	52.3	104	85.3	95.3	158	188	223	233
Heavy-Duty Diesel Vehicles	3 650	3 490	3 580	3 900	4 740	4 920	5 470	6 250	6 240	6 300	6 840	7 080	6 840	7 500
Propane & Natural Gas Vehicles	630	630	700	320	510	510	550	480	430	340	270	270	210	190
Railways	2 000	2 000	2 000	2 000	2 000	1 000	1 000	1 000	1 000	1 000	2 000	2 000	2 000	2 000
Domestic Marine	0.30	–	0.61	0.61	0.30	0.61	0.30	–	–	–	0.00	0.02	0.02	0.01
Others	5 000	5 000	5 000	6 000	6 000	7 000	8 000	9 000	9 000	9 000	8 000	9 000	8 000	8 000
Off-Road Gasoline	1 000	1 000	1 000	1 000	700	600	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000
Off-Road Diesel	3 000	2 000	2 000	2 000	3 000	3 000	4 000	4 000	5 000	4 000	5 000	4 000	4 000	4 000
Pipelines	1 270	1 360	1 920	2 100	2 600	2 670	2 780	3 160	3 250	3 210	2 670	3 420	3 470	3 090
c. Fugitive Sources	**25 000**	**26 100**	**28 300**	**29 500**	**30 600**	**32 300**	**34 100**	**33 600**	**33 500**	**33 800**	**33 900**	**33 600**	**32 700**	**32 300**
Coal Mining	200	200	300	300	300	300	300	300	300	200	200	200	200	200
Oil and Natural Gas	24 800	25 900	28 000	29 200	30 300	32 000	33 800	33 400	33 300	33 600	33 700	33 400	32 500	32 100
INDUSTRIAL PROCESSES	**8 800**	**9 200**	**9 180**	**9 970**	**10 500**	**10 400**	**11 300**	**12 100**	**11 600**	**11 400**	**11 100**	**7 770**	**7 400**	**8 540**
a. Mineral Production[1]	**870**	**660**	**730**	**790**	**860**	**900**	**880**	**1 100**	**1 100**	**1 100**	**1 100**	**1 100**	**1 200**	**1 200**
Cement	760	550	620	670	730	770	760	950	940	1 000	960	940	1 000	1 000
Lime	100	100	100	100	100	100	100	100	100	100	100	200	100	100
b. Chemical Industry[2]	**660**	**650**	**660**	**660**	**650**	**660**	**670**	**670**	**660**	**670**	**670**	**670**	**680**	**670**
Nitric Acid Production	660	650	660	660	650	660	670	670	660	670	670	670	680	670
Adipic Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Metal Production	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Iron and Steel Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
e. Other & Undifferentiated Production[2]	**7 300**	**7 900**	**7 800**	**8 500**	**8 900**	**8 800**	**9 700**	**10 000**	**9 900**	**9 600**	**9 400**	**6 000**	**5 600**	**6 700**
SOLVENT & OTHER PRODUCT USE	**38**	**39**	**40**	**40**	**41**	**41**	**42**	**43**	**44**	**44**	**45**	**46**	**47**	**48**
AGRICULTURE	**15 000**	**15 000**	**15 000**	**16 000**	**17 000**	**17 000**	**18 000**	**18 000**	**18 000**	**19 000**	**19 000**	**19 000**	**19 000**	**19 000**
a. Enteric Fermentation	**6 090**	**6 280**	**6 550**	**6 690**	**7 230**	**7 460**	**7 420**	**7 490**	**7 480**	**7 700**	**7 830**	**8 720**	**8 630**	**8 160**
b. Manure Management	**1 500**	**1 600**	**1 600**	**1 700**	**1 800**	**1 800**	**1 800**	**1 800**	**1 800**	**1 900**	**1 900**	**2 100**	**2 100**	**2 000**
c. Agricultural Soils	**7 400**	**7 300**	**7 200**	**7 700**	**8 000**	**8 200**	**8 500**	**8 300**	**8 500**	**9 100**	**9 100**	**8 500**	**7 800**	**8 500**
Direct Sources	5 900	5 800	5 600	6 100	6 300	6 500	6 700	6 500	6 700	7 200	7 100	6 600	5 800	6 700
Indirect Sources	1 000	1 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
WASTE	**1 000**	**1 100**	**920**	**960**	**1 000**	**1 000**	**990**	**1 100**	**1 100**	**1 200**	**1 200**	**1 300**	**1 300**	**1 400**
a. Solid Waste Disposal on Land	**870**	**930**	**780**	**820**	**860**	**890**	**850**	**900**	**940**	**1 000**	**1 100**	**1 100**	**1 200**	**1 200**
b. Wastewater Handling	**140**	**140**	**140**	**140**	**140**	**150**	**150**	**150**	**150**	**160**	**160**	**160**	**170**	**170**
c. Waste Incineration	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

Totals may not add due to rounding.

TABLE A12-19: 2003 Greenhouse Gas Emissions Summary for Alberta

					Greenhouse Gases				
GHG Source Category	**CO_2**	**CH_4**	**CH_4**	**N_2O**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**TOTAL**
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**176 000**	**1 700**	**36 000**	**42**	**13 000**	**–**	**–**	**–**	**224 000**
ENERGY	**168 000**	**1 000**	**30 000**	**8**	**2 000**	**–**	**–**	**–**	**196 000**
a. Stationary Combustion Sources	**129 000**	**90**	**2 000**	**3**	**900**	**–**	**–**	**–**	**132 000**
Electricity and Heat Generation	54 500	1.7	35	1	300	–	–	–	54 900
Fossil Fuel Industries	41 000	90	2 000	1	300	–	–	–	43 000
Mining	10 900	0.2	4	0.2	70	–	–	–	11 000
Manufacturing Industries	7 760	0.4	8	0.2	70	–	–	–	7 830
Construction	156	0.00	0.06	0.01	2	–	–	–	158
Commercial & Institutional	6 020	0.1	2	0.1	40	–	–	–	6 070
Residential	8 070	2	50	0.2	60	–	–	–	8 200
Agriculture & Forestry	268	0.01	0.1	0.01	2	–	–	–	270
b. Transportation	**30 100**	**6**	**100**	**5**	**1 000**	**–**	**–**	**–**	**32 000**
Domestic Aviation	1 250	0.08	2	0.1	40	–	–	–	1 300
Road Transportation	19 100	1.7	37	2.3	700	–	–	–	19 900
Light-Duty Gasoline Vehicles	4 420	0.40	8.4	0.60	190	–	–	–	4 620
Light-Duty Gasoline Trucks	5 750	0.69	14	1.30	390	–	–	–	6 160
Heavy-Duty Gasoline Vehicles	1 040	0.15	3.1	0.15	48	–	–	–	1 090
Motorcycles	23.6	0.02	0.40	0.00	0.14	–	–	–	24.2
Light-Duty Diesel Vehicles	51.2	0.00	0.03	0.00	1	–	–	–	52.4
Light-Duty Diesel Trucks	228.0	0.01	0.1	0.02	5	–	–	–	233.0
Heavy-Duty Diesel Vehicles	7 420	0.4	8	0.2	70	–	–	–	7 500
Propane & Natural Gas Vehicles	187	0.1	2	0.00	1	–	–	–	190
Railways	2 170	0.1	3	0.9	300	–	–	–	2 000
Domestic Marine	0.01	0.00	0.00	0.00	0.00	–	–	–	0.01
Others	7 600	4	90	2	500	–	–	–	8 000
Off-Road Gasoline	1 000	1	20	0.02	7	–	–	–	1 000
Off-Road Diesel	3 500	0.2	4	1	400	–	–	–	4 000
Pipelines	3 000	3.0	63	0.08	20	–	–	–	3 090
c. Fugitive Sources	**8 800**	**1 100**	**24 000**	**–**	**–**	**–**	**–**	**–**	**32 300**
Coal Mining	–	9	200	–	–	–	–	–	200
Oil and Natural Gas	8 800	1 100	23 000	–	–	–	–	–	32 100
INDUSTRIAL PROCESSES	**7 860**	**–**	**–**	**2.18**	**675**	**–**	**–**	**–**	**8 540**
a. Mineral Production[1]	**1 200**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**1 200**
Cement	1 000	–	–	–	–	–	–	–	1 000
Lime	100	–	–	–	–	–	–	–	100
b. Chemical Industry[2]	**–**	**–**	**–**	**2.18**	**675**	**–**	**–**	**–**	**670**
Nitric Acid Production	–	–	–	2.2	670	–	–	–	670
Adipic Acid Production	–	–	–	–	–	–	–	–	–
c. Metal Production	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Iron and Steel Production	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
e. Other & Undifferentiated Production[2]	**6 700**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**6 700**
SOLVENT & OTHER PRODUCT USE	**–**	**–**	**–**	0.15	**48**	**–**	**–**	**–**	**48**
AGRICULTURE	**–**	**419**	**8 810**	**32**	**9 800**	**–**	**–**	**–**	**19 000**
a. Enteric Fermentation	**–**	**389**	**8 160**	**–**	**–**	**–**	**–**	**–**	**8 160**
b. Manure Management	**–**	**31**	**640**	**4.3**	**1 300**	**–**	**–**	**–**	**2 000**
c. Agricultural Soils	**–**	**–**	**–**	**27**	**8 500**	**–**	**–**	**–**	**8 500**
Direct Sources	–	–	–	22	6 700	–	–	–	6 700
Indirect Sources	–	–	–	6	2 000	–	–	–	2 000
WASTE	**–**	**61**	**1 300**	**0.3**	**100**	**–**	**–**	**–**	**1 400**
a. Solid Waste Disposal on Land	**–**	**58**	**1 200**	**–**	**–**	**–**	**–**	**–**	**1 200**
b. Wastewater Handling	**–**	**3.3**	**70**	**0.3**	**100**	**–**	**–**	**–**	**170**
c. Waste Incineration	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

Totals may not add due to rounding.

TABLE A12-20: 1990–2003 Greenhouse Gas Emissions Summary for British Columbia

kt CO$_2$ eq

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
TOTAL	**51 300**	**50 700**	**50 000**	**52 700**	**55 100**	**59 600**	**61 300**	**59 900**	**60 500**	**62 600**	**64 300**	**63 400**	**62 200**	**63 400**
ENERGY	**41 400**	**40 700**	**40 000**	**42 300**	**44 200**	**48 100**	**50 400**	**48 800**	**49 700**	**51 400**	**52 600**	**53 100**	**51 800**	**52 700**
a. Stationary Combustion Sources	**19 100**	**17 800**	**16 500**	**18 000**	**18 000**	**20 000**	**21 600**	**19 200**	**19 600**	**21 300**	**22 200**	**22 100**	**20 400**	**20 300**
Electricity and Heat Generation	1 170	1 040	1 270	2 340	2 180	2 700	768	1 190	1 870	1 300	2 480	3 070	1 180	1 330
Fossil Fuel Industries	3 900	3 100	2 000	1 100	2 000	2 700	4 800	3 000	3 700	5 200	3 800	3 100	3 800	4 700
Mining	253	225	271	336	202	163	449	344	324	228	316	233	271	156
Manufacturing Industries	5 990	5 460	4 990	5 340	5 500	6 250	6 860	6 420	6 030	6 580	7 190	7 400	6 500	6 430
Construction	304	268	317	340	283	198	207	126	100	85.8	75.6	70.4	73.5	81.2
Commercial & Institutional	2 820	3 070	3 180	3 560	3 290	3 360	3 400	3 290	2 880	2 960	3 390	3 440	4 130	3 430
Residential	4 300	4 200	4 100	4 600	4 400	4 400	4 900	4 500	4 400	4 700	4 600	4 500	4 300	4 100
Agriculture & Forestry	323	375	374	374	205	155	191	270	253	263	315	357	126	80.7
b. Transportation	**19 000**	**19 000**	**20 000**	**20 000**	**21 000**	**23 000**	**23 000**	**24 000**	**24 000**	**24 000**	**24 000**	**24 000**	**24 000**	**25 000**
Domestic Aviation	1 100	1 000	1 000	900	1 000	1 200	1 200	1 300	1 300	1 500	1 400	1 100	1 400	1 300
Road Transportation	12 400	12 500	12 600	13 100	13 900	14 300	14 400	15 000	15 500	15 500	15 400	15 400	15 500	16 000
Light-Duty Gasoline Vehicles	5 380	5 320	5 270	5 360	5 410	5 320	5 210	5 400	5 450	5 330	5 100	5 030	4 940	4 930
Light-Duty Gasoline Trucks	2 770	2 970	3 180	3 480	3 770	3 980	4 170	4 550	4 850	5 150	5 170	5 170	5 260	5 410
Heavy-Duty Gasoline Vehicles	352	417	485	567	647	713	720	667	827	622	596	524	516	507
Motorcycles	39.0	38.9	39.5	39.2	40.1	39.7	39.0	43.0	44.9	47.3	46.3	44.4	41.4	41.7
Light-Duty Diesel Vehicles	74.5	71.6	68.5	66.7	63.9	59.2	65.9	65.9	69.4	71.5	64.5	67.5	70.7	77.0
Light-Duty Diesel Trucks	78.5	59.7	49.1	42.8	39.8	36.8	33.8	41.1	38.8	26.3	60.2	71.7	86.0	96.4
Heavy-Duty Diesel Vehicles	2 920	2 840	2 880	3 010	3 290	3 530	3 710	3 850	3 750	3 950	4 060	4 150	4 350	4 640
Propane & Natural Gas Vehicles	780	770	580	490	620	570	410	400	480	310	330	320	290	260
Railways	1 000	1 000	2 000	2 000	2 000	2 000	2 000	1 000	1 000	1 000	1 000	1 000	900	600
Domestic Marine	1 000	1 100	1 100	1 100	1 200	1 200	1 100	1 000	1 000	1 100	1 200	1 600	1 900	3 000
Others	3 000	3 000	3 000	3 000	4 000	4 000	5 000	5 000	5 000	5 000	5 000	5 000	4 000	5 000
Off-Road Gasoline	400	400	400	500	600	600	600	700	600	600	700	600	600	700
Off-Road Diesel	2 000	2 000	2 000	2 000	2 000	2 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000
Pipelines	846	1 090	1 040	1 110	1 240	1 370	1 490	1 430	1 560	1 390	1 630	1 840	1 340	1 050
c. Fugitive Sources	**3 460**	**3 600**	**3 840**	**4 100**	**4 820**	**5 430**	**5 770**	**5 840**	**5 930**	**5 880**	**6 070**	**6 830**	**7 290**	**6 950**
Coal Mining	500	500	400	500	500	600	600	700	600	500	500	500	500	500
Oil and Natural Gas	2 970	3 120	3 480	3 630	4 300	4 860	5 140	5 180	5 380	5 390	5 600	6 310	6 770	6 430
INDUSTRIAL PROCESSES	**3 790**	**3 720**	**3 560**	**3 950**	**4 110**	**4 590**	**3 640**	**3 760**	**3 550**	**3 870**	**4 410**	**2 670**	**2 560**	**2 710**
a. Mineral Production[1]	**790**	**710**	**770**	**830**	**900**	**920**	**940**	**1 100**	**1 100**	**1 300**	**1 300**	**1 200**	**1 300**	**1 300**
Cement	630	550	610	650	710	730	760	860	870	1 100	1 100	1 000	1 100	1 100
Lime	200	200	200	200	200	200	200	200	200	200	200	200	200	200
b. Chemical Industry[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitric Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	**1 800**	**1 760**	**1 710**	**1 670**	**1 630**	**2 040**	**1 540**	**1 490**	**1 450**	**1 400**	**1 820**	**1 270**	**1 060**	**1 230**
Iron and Steel Production	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminium Production	1 800	1 760	1 710	1 670	1 630	2 040	1 540	1 490	1 450	1 400	1 820	1 270	1 060	1 230
SF$_6$ Used in Magnesium Smelters and Casters	-	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons and SF$_6$[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
e. Other & Undifferentiated Production[2]	**1 200**	**1 200**	**1 100**	**1 400**	**1 600**	**1 600**	**1 200**	**1 200**	**1 000**	**1 200**	**1 300**	**180**	**230**	**230**
SOLVENT & OTHER PRODUCT USE	**50**	**51**	**52**	**54**	**55**	**57**	**58**	**59**	**60**	**60**	**61**	**61**	**62**	**62**
AGRICULTURE	**2 400**	**2 300**	**2 300**	**2 400**	**2 500**	**2 500**	**2 600**	**2 600**	**2 300**	**2 400**	**2 300**	**2 500**	**2 500**	**2 500**
a. Enteric Fermentation	**1 070**	**1 090**	**1 120**	**1 110**	**1 190**	**1 240**	**1 240**	**1 200**	**1 150**	**1 150**	**1 140**	**1 190**	**1 220**	**1 260**
b. Manure Management	**360**	**360**	**370**	**370**	**380**	**400**	**400**	**390**	**390**	**390**	**390**	**400**	**410**	**420**
c. Agricultural Soils	**930**	**820**	**860**	**900**	**910**	**890**	**930**	**960**	**740**	**830**	**760**	**860**	**820**	**860**
Direct Sources	730	630	650	690	700	680	720	740	570	650	580	660	630	660
Indirect Sources	200	200	200	200	200	200	200	200	200	200	200	200	200	200
WASTE	**3 600**	**3 900**	**4 000**	**4 100**	**4 200**	**4 300**	**4 600**	**4 800**	**4 900**	**4 800**	**5 000**	**5 200**	**5 300**	**5 400**
a. Solid Waste Disposal on Land	**3 400**	**3 700**	**3 800**	**3 800**	**3 900**	**4 000**	**4 300**	**4 500**	**4 600**	**4 500**	**4 600**	**4 900**	**5 000**	**5 100**
b. Wastewater Handling	**180**	**190**	**190**	**200**	**210**	**210**	**220**	**220**	**220**	**230**	**230**	**230**	**230**	**230**
c. Waste Incineration	**67**	**68**	**70**	**72**	**75**	**77**	**79**	**80**	**81**	**81**	**82**	**83**	**83**	**84**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

Totals may not add due to rounding.

TABLE A12-21: 2003 Greenhouse Gas Emissions Summary for British Columbia

	Greenhouse Gases								
GHG Source Category	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			21		310				
Unit	kt	kt	kt CO_2 eq	kt	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq
TOTAL	**50 000**	**470**	**9 900**	**9.0**	**2 800**	–	**794**	–	**63 400**
ENERGY	**48 000**	**200**	**3 000**	**5**	**1 000**	–	–	–	**52 700**
a. Stationary Combustion Sources	**19 600**	**20**	**400**	**0.8**	**200**	–	–	–	**20 300**
Electricity and Heat Generation	1 320	0.19	4.0	0.03	10	–	–	–	1 330
Fossil Fuel Industries	4 400	10	200	0.1	40	–	–	–	4 700
Mining	154	0.00	0.04	0.00	1	–	–	–	156
Manufacturing Industries	6 290	0.8	20	0.4	100	–	–	–	6 430
Construction	80.7	0.00	0.03	0.00	1	–	–	–	81.2
Commercial & Institutional	3 410	0.06	1	0.07	20	–	–	–	3 430
Residential	3 860	8	200	0.2	50	–	–	–	4 100
Agriculture & Forestry	80.1	0.00	0.03	0.00	1	–	–	–	80.7
b. Transportation	**24 200**	**4**	**80**	**4**	**1 000**	–	–	–	**25 000**
Domestic Aviation	1 310	0.07	2	0.1	40	–	–	–	1 300
Road Transportation	15 300	1.5	32	2.1	660	–	–	–	16 000
Light-Duty Gasoline Vehicles	4 700	0.42	8.9	0.70	220	–	–	–	4 930
Light-Duty Gasoline Trucks	5 020	0.59	12	1.20	370	–	–	–	5 410
Heavy-Duty Gasoline Vehicles	483	0.07	1.4	0.07	22	–	–	–	507
Motorcycles	40.7	0.03	0.69	0.00	0.25	–	–	–	41.7
Light-Duty Diesel Vehicles	75.2	0.00	0.04	0.01	2	–	–	–	77.0
Light-Duty Diesel Trucks	94.3	0.00	0.05	0.01	2	–	–	–	96.4
Heavy-Duty Diesel Vehicles	4 600	0.2	5	0.1	40	–	–	–	4 640
Propane & Natural Gas Vehicles	250	0.2	4	0.01	1	–	–	–	260
Railways	506	0.03	0.6	0.2	60	–	–	–	600
Domestic Marine	2 860	0.20	5	0.4	100	–	–	–	3 000
Others	4 200	2	40	1	300	–	–	–	5 000
Off-Road Gasoline	600	0.7	20	0.01	4	–	–	–	700
Off-Road Diesel	2 600	0.1	3	1	300	–	–	–	3 000
Pipelines	1 020	1.0	21	0.03	9	–	–	–	1 050
c. Fugitive Sources	**4 200**	**130**	**2 800**	–	–	–	–	–	**6 950**
Coal Mining	–	20	500	–	–	–	–	–	500
Oil and Natural Gas	4 200	110	2 200	–	–	–	–	–	6 430
INDUSTRIAL PROCESSES	**1 920**	–	–	–	–	–	**794**	–	**2 710**
a. Mineral Production[1]	**1 300**	–	–	–	–	–	–	–	**1 300**
Cement	1 100	–	–	–	–	–	–	–	1 100
Lime	200	–	–	–	–	–	–	–	200
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–
c. Metal Production	**430**	–	–	–	–	–	**794**	–	**1 230**
Iron and Steel Production	–	–	–	–	–	–	–	–	–
Aluminium Production	430	–	–	–	–	–	794	–	1 230
SF_6 Used in Magnesium Smelters and Casters[3]	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**230**	–	–	–	–	–	–	–	**230**
SOLVENT & OTHER PRODUCT USE	–	–	–	0.20	**62**	–	–	–	**62**
AGRICULTURE	–	**67.4**	**1 410**	**3.6**	**1 100**	–	–	–	**2 500**
a. Enteric Fermentation	–	**60.1**	**1 260**	–	–	–	–	–	**1 260**
b. Manure Management	–	**7.2**	**150**	**0.87**	**270**	–	–	–	**420**
c. Agricultural Soils	–	–	–	**2.8**	**860**	–	–	–	**860**
Direct Sources	–	–	–	2.1	660	–	–	–	660
Indirect Sources	–	–	–	0.7	200	–	–	–	200
WASTE	**70**	**250**	**5 200**	**0.5**	**100**	–	–	–	**5 400**
a. Solid Waste Disposal on Land	–	**240**	**5 100**	–	–	–	–	–	**5 100**
b. Wastewater Handling	–	**4.9**	**100**	**0.4**	**100**	–	–	–	**230**
c. Waste Incineration	**70**	–	–	**0.05**	**10**	–	–	–	**84**

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

3 Information on SF_6 use in Casters is confidential for this province.

Totals may not add due to rounding.

TABLE A12-22: 1990–2003 Greenhouse Gas Emissions Summary for Yukon

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
							kt CO_2 eq							
TOTAL	**514**	**499**	**622**	**529**	**594**	**658**	**685**	**597**	**524**	**566**	**518**	**482**	**485**	**470**
ENERGY	**504**	**481**	**613**	**497**	**484**	**566**	**612**	**586**	**514**	**557**	**509**	**473**	**475**	**460**
a. Stationary Combustion Sources	**196**	**154**	**229**	**175**	**164**	**237**	**260**	**244**	**203**	**216**	**197**	**176**	**182**	**173**
Electricity and Heat Generation	96.0	58.8	54.0	30.9	28.0	54.8	104.0	89.1	33.1	26.6	17.4	14.9	17.6	10.9
Fossil Fuel Industries[1]	3.1	2.8	92	60	50	92	75	81	93	91	82	55	51	30
Mining	3.07	3.12	0.26	0.54	1.65	8.78	12.30	3.92	2.84	5.66	4.41	4.83	6.96	5.61
Manufacturing Industries	1.67	1.13	1.11	1.67	0.85	0.79	0.25	0.53	0.00	0.00	0.00	0.03	0.00	0.00
Construction	1.42	1.11	0.57	–	1.68	4.38	3.52	2.67	1.56	2.27	2.29	1.44	1.43	2.47
Commercial & Institutional	70.7	67.6	60.9	55.8	49.3	51.5	37.3	35.7	33.4	39.6	53.6	51.8	54.0	58.4
Residential	20	15	12	22	27	17	22	25	32	41	36	33	36	45
Agriculture & Forestry	0.57	3.95	8.46	5.08	5.68	7.64	5.96	5.96	7.67	10.6	0.98	14.4	15.2	20.7
b. Transportation	**310**	**310**	**340**	**270**	**270**	**290**	**310**	**300**	**270**	**280**	**260**	**250**	**260**	**260**
Domestic Aviation	21	19	16	17	19	21	24	16	23	21	23	16	15	20
Road Transportation	183	183	196	196	239	248	244	190	226	254	232	214	220	207
Light-Duty Gasoline Vehicles	80.3	80.0	83.8	84.6	75.6	75.7	69.8	65.9	74.5	69.7	52.3	52.3	50.4	50.3
Light-Duty Gasoline Trucks	34.5	36.7	41.0	44.0	41.7	42.2	41.1	42.2	52.3	55.1	43.9	44.8	44.6	46.1
Heavy-Duty Gasoline Vehicles	5.73	6.38	7.40	8.19	7.96	8.08	8.04	8.25	10.1	14.3	11.4	10.4	10.2	10.1
Motorcycles	0.38	0.39	0.40	0.41	0.37	0.38	0.34	0.32	0.40	0.40	0.32	0.32	0.33	0.32
Light-Duty Diesel Vehicles	0.96	0.96	1.00	1.00	0.88	0.89	0.81	0.79	0.88	0.84	0.65	0.68	0.69	0.73
Light-Duty Diesel Trucks	1.20	0.99	0.91	0.76	1.30	1.43	1.34	0.72	0.94	0.66	0.95	0.86	0.98	0.86
Heavy-Duty Diesel Vehicles	58.8	56.2	58.9	54.9	105	115	120	70.0	85.4	112	122	104	111	97.2
Propane & Natural Gas Vehicles	1.5	1.5	2.9	2.3	5.9	4.0	2.2	1.9	1.7	1.6	0.68	1.0	1.5	1.7
Railways	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Domestic Marine	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Others	100	100	100	60	20	20	40	100	20	6	4	20	20	30
Off-Road Gasoline	20	10	8	9	8	10	10	9	9	6	4	5	4	5
Off-Road Diesel	90	90	100	50	9	7	30	90	10	–	–	20	20	30
Pipelines	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Fugitive Sources	**–**	**19.7**	**47.4**	**48.4**	**45.4**	**42.4**	**40.4**	**38.4**	**42.6**	**58.6**	**53.3**	**44.8**	**35.2**	**24.9**
Coal Mining	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oil and Natural Gas	–	19.7	47.4	48.4	45.4	42.4	40.4	38.4	42.6	58.6	53.3	44.8	35.2	24.9
INDUSTRIAL PROCESSES	**2.88**	**10.7**	**1.55**	**23.9**	**102.0**	**84.0**	**64.4**	**2.69**	**1.27**	**0.81**	**0.71**	**0.61**	**0.99**	**0.75**
a. Mineral Production[2]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cement	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lime	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b. Chemical Industry[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[2]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[3]	**2.9**	**11**	**1.6**	**24**	**100**	**84**	**64**	**2.7**	**1.3**	**0.81**	**0.71**	**0.61**	**0.99**	**0.75**
SOLVENT & OTHER PRODUCT USE	**0.42**	**0.44**	**0.45**	**0.46**	**0.45**	**0.46**	**0.47**	**0.48**	**0.47**	**0.46**	**0.46**	**0.45**	**0.45**	**0.47**
AGRICULTURE	–	–	–	–	–	–	–	–	–	–	–	–	–	–
a. Enteric Fermentation	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b. Manure Management	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Agricultural Soils	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Direct Sources	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Indirect Sources	–	–	–	–	–	–	–	–	–	–	–	–	–	–
WASTE	**6.70**	**7.00**	**7.20**	**7.40**	**7.50**	**7.70**	**7.90**	**8.10**	**8.20**	**8.30**	**8.40**	**8.50**	**8.70**	**8.90**
a. Solid Waste Disposal on Land	**3.60**	**3.70**	**3.80**	**3.90**	**4.10**	**4.20**	**4.40**	**4.50**	**4.70**	**4.80**	**4.90**	**5.10**	**5.20**	**5.40**
b. Wastewater Handling	**3.20**	**3.30**	**3.40**	**3.50**	**3.40**	**3.50**	**3.60**	**3.60**	**3.60**	**3.50**	**3.50**	**3.40**	**3.40**	**3.50**
c. Waste Incineration	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Notes:

1 The GHG emissions associated with natural gas processing in the Yukon also include the processing emissions that occur in British Columbia.

2 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

3 Ammonia production emissions are included under undifferentiated production at the provincial level.

Totals may not add due to rounding.

TABLE A12-23: 2003 Greenhouse Gas Emissions Summary for Yukon

GHG Source Category	CO$_2$	CH$_4$	CH$_4$	N$_2$O	N$_2$O	HFCs	PFCs	SF$_6$	TOTAL
	Greenhouse Gases								
Global Warming Potential			21		310				
Unit	kt	kt	kt CO$_2$ eq	kt	kt CO$_2$ eq	kt CO$_2$ eq	kt CO$_2$ eq	kt CO$_2$ eq	kt CO$_2$ eq
TOTAL	**420**	**1.7**	**36**	**0.044**	**14**	–	–	–	**470**
ENERGY	**420**	**1**	**30**	**0.04**	**10**	–	–	–	**460**
a. Stationary Combustion Sources	**167**	**0.2**	**4**	**0.01**	**2**	–	–	–	**173**
Electricity and Heat Generation	10.4	0.00	0.01	0.00	0.5	–	–	–	10.9
Fossil Fuel Industries[1]	28.0	0.08	2	0.00	0.2	–	–	–	30
Mining	5.49	0.00	0.00	0.00	0.1	–	–	–	5.61
Manufacturing Industries	–	0.00	0.00	0.00	0.00	–	–	–	0.00
Construction	2.46	0.00	0.00	0.00	0.02	–	–	–	2.47
Commercial & Institutional	57.9	0.00	0.01	0.00	0.5	–	–	–	58.4
Residential	42.3	0.1	2	0.00	0.6	–	–	–	45
Agriculture & Forestry	20.6	0.00	0.00	0.00	0.07	–	–	–	20.7
b. Transportation	**252**	**0.03**	**0.5**	**0.03**	**10**	–	–	–	**260**
Domestic Aviation	19.7	0.00	0.05	0.00	0.6	–	–	–	20
Road Transportation	201	0.02	0.35	0.02	6.3	–	–	–	207
Light-Duty Gasoline Vehicles	48.1	0.00	0.09	0.01	2.0	–	–	–	50.3
Light-Duty Gasoline Trucks	43.0	0.01	0.11	0.01	3.0	–	–	–	46.1
Heavy-Duty Gasoline Vehicles	9.65	0.00	0.03	0.00	0.44	–	–	–	10.10
Motorcycles	0.31	0.00	0.01	0.00	0.00	–	–	–	0.32
Light-Duty Diesel Vehicles	0.72	0.00	0.00	0.00	0.02	–	–	–	0.73
Light-Duty Diesel Trucks	0.84	0.00	0.00	0.00	0.02	–	–	–	0.86
Heavy-Duty Diesel Vehicles	96.2	0.01	0.1	0.00	0.9	–	–	–	97.2
Propane & Natural Gas Vehicles	1.72	0.00	0.01	0.00	0.01	–	–	–	1.7
Railways	–	–	–	–	–	–	–	–	–
Domestic Marine	–	–	–	–	–	–	–	–	–
Others	31	0.01	0.1	0.01	3	–	–	–	30
Off-Road Gasoline	4	0.01	0.1	0.00	0.03	–	–	–	5
Off-Road Diesel	27	0.00	0.03	0.01	3	–	–	–	30
Pipelines	–	–	–	–	–	–	–	–	–
c. Fugitive Sources	**0.89**	**1.1**	**24**	–	–	–	–	–	**24.9**
Coal Mining	–	–	–	–	–	–	–	–	–
Oil and Natural Gas	0.89	1.1	24	–	–	–	–	–	24.9
INDUSTRIAL PROCESSES	**0.75**	–	–	–	–	–	–	–	**0.75**
a. Mineral Production[2]	–	–	–	–	–	–	–	–	–
Cement	–	–	–	–	–	–	–	–	–
Lime	–	–	–	–	–	–	–	–	–
b. Chemical Industry[3]	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–
SF$_6$ Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF$_6$[2]	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[3]	**0.75**	–	–	–	–	–	–	–	**0.75**
SOLVENT & OTHER PRODUCT USE	–	–	–	**0.00**	**0.47**	–	–	–	**0.47**
AGRICULTURE	–	–	–	–	–	–	–	–	–
a. Enteric Fermentation	–	–	–	–	–	–	–	–	–
b. Manure Management	–	–	–	–	–	–	–	–	–
c. Agricultural Soils	–	–	–	–	–	–	–	–	–
Direct Sources	–	–	–	–	–	–	–	–	–
Indirect Sources	–	–	–	–	–	–	–	–	–
WASTE	–	**0.38**	**7.9**	**0.00**	**1**	–	–	–	**8.9**
a. Solid Waste Disposal on Land	–	**0.26**	**5.4**	–	–	–	–	–	**5.4**
b. Wastewater Handling	–	**0.12**	**2.6**	**0.00**	**1**	–	–	–	**3.5**
c. Waste Incineration	–	–	–	–	–	–	–	–	–

Notes:

1 The GHG emissions associated with natural gas processing in the Yukon also include the processing emissions that occur in British Columbia.

2 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

3 Ammonia production emissions are included under undifferentiated production at the provincial level.

Totals may not add due to rounding.

TABLE A12-24: 1990–2003 Greenhouse Gas Emissions Summary for Northwest Territories and Nunavut

kt CO_2 eq

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
TOTAL	**1530**	**1480**	**1300**	**1570**	**1710**	**1810**	**1680**	**1730**	**1580**	**1380**	**1700**	**2300**	**1900**	**1760**
ENERGY	**1520**	**1460**	**1280**	**1550**	**1690**	**1790**	**1660**	**1710**	**1560**	**1360**	**1680**	**2270**	**1870**	**1730**
a. Stationary Combustion Sources	**911**	**950**	**807**	**908**	**988**	**1120**	**817**	**922**	**746**	**636**	**808**	**983**	**881**	**736**
Electricity and Heat Generation	215	215	186	197	198	371	351	348	326	302	293	302	258	223
Fossil Fuel Industries	190	110	11	25	31	31	15	0.45	0.53	0.31	160	290	260	150
Mining	50.8	55.6	41.4	65.9	152	103	44.4	49.3	63.8	68.9	76.6	103	103	90.5
Manufacturing Industries	31.6	21.1	23.1	8.53	14.2	20.5	18.4	9.63	0.28	0.00	0.00	0.02	0.00	0.07
Construction	7.59	7.32	7.76	6.87	4.04	20.40	0.85	0.57	0.44	0.92	0.67	0.91	1.61	1.42
Commercial & Institutional	250	341	332	371	392	454	197	339	214	172	163	153	127	160
Residential	170	190	190	230	190	120	190	180	140	92	120	110	110	93
Agriculture & Forestry	2.34	9.70	12.4	2.22	1.99	–	–	–	–	0.01	0.01	20.3	22.7	15.7
b. Transportation	**550**	**450**	**420**	**580**	**650**	**620**	**790**	**750**	**760**	**670**	**740**	**1 100**	**810**	**840**
Domestic Aviation	170	170	180	200	220	180	200	210	170	110	110	210	140	140
Road Transportation	120	100	100	77.0	105	149	144	138	282	206	232	222	269	294
Light-Duty Gasoline Vehicles	27.9	24.1	23.6	25.5	27.9	27.1	22.2	26.5	25.4	39.5	45.0	50.1	41.9	40.5
Light-Duty Gasoline Trucks	12.0	11.0	11.5	13.2	15.4	15.8	14.1	18.0	17.8	31.2	37.8	42.8	37.1	37.2
Heavy-Duty Gasoline Vehicles	1.99	1.92	2.08	2.47	2.93	3.08	2.75	3.32	3.46	6.34	8.01	8.18	7.01	6.76
Motorcycles	0.13	0.12	0.11	0.12	0.14	0.13	0.11	0.14	0.14	0.21	0.27	0.26	0.21	0.21
Light-Duty Diesel Vehicles	0.33	0.29	0.28	0.30	0.32	0.31	0.27	0.32	0.30	0.47	0.56	0.65	0.57	0.59
Light-Duty Diesel Trucks	1.52	1.05	0.92	0.45	0.64	1.09	1.04	1.01	2.54	0.95	1.32	1.18	1.91	2.18
Heavy-Duty Diesel Vehicles	75.1	59.5	58.9	32.7	51.7	97.4	102	86.9	230	125	138	117	179	205
Propane & Natural Gas Vehicles	1.5	1.5	2.9	2.3	5.9	4.0	2.2	1.9	1.7	1.6	0.68	1.0	1.5	1.7
Railways	3	2	2	2	2	2	1	3	2	3	3	4	4	3
Domestic Marine	–	0.30	0.61	0.61	–	71	90	12	31	8.4	10	17	10	-
Others	300	200	100	300	300	200	400	400	300	300	400	600	400	400
Off-Road Gasoline	60	60	60	90	80	70	70	90	40	30	30	20	10	20
Off-Road Diesel	200	100	70	200	200	100	300	300	200	300	400	600	400	400
Pipelines	–	–	–	–	2.57	–	–	–	5.14	4.84	5.80	6.19	3.73	3.01
c. Fugitive Sources	**57.7**	**61.1**	**58.6**	**60.8**	**52.8**	**53.2**	**49.6**	**47.5**	**45.5**	**44.2**	**124**	**193**	**182**	**153**
Coal Mining	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Oil and Natural Gas	57.7	61.1	58.6	60.8	52.8	53.2	49.6	47.5	45.5	44.2	124	193	182	153
INDUSTRIAL PROCESSES	**0.85**	**0.56**	**0.85**	**0.42**	**0.28**	**2.26**	**1.83**	**0.85**	**0.42**	**2.46**	**4.23**	**5.41**	**5.42**	**5.38**
a. Mineral Production[1]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Cement	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Lime	–	–	–	–	–	–	–	–	–	–	–	–	–	-
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Nitric Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Adipic Acid Production	–	–	–	–	–	–	–	–	–	–	–	–	–	-
c. Metal Production	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Iron and Steel Production	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Aluminium Production	–	–	–	–	–	–	–	–	–	–	–	–	–	-
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–	–	–	–	–	-
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–	–	–	–	–	-
e. Other & Undifferentiated Production[2]	**0.85**	**0.56**	**0.85**	**0.42**	**0.28**	**2.3**	**1.8**	**0.85**	**0.42**	**2.5**	**4.2**	**5.4**	**5.4**	**5.4**
SOLVENT & OTHER PRODUCT USE	**0.89**	**0.92**	**0.94**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.1**	**1.1**
AGRICULTURE	–	–	–	–	–	–	–	–	–	–	–	–	–	-
a. Enteric Fermentation	–	–	–	–	–	–	–	–	–	–	–	–	–	-
b. Manure Management	–	–	–	–	–	–	–	–	–	–	–	–	–	-
c. Agricultural Soils	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Direct Sources	–	–	–	–	–	–	–	–	–	–	–	–	–	-
Indirect Sources	–	–	–	–	–	–	–	–	–	–	–	–	–	-
WASTE	**14**	**14**	**15**	**15**	**16**	**16**	**17**	**17**	**17**	**18**	**18**	**19**	**19**	**20**
a. Solid Waste Disposal on Land	**7.1**	**7.3**	**7.6**	**7.9**	**8.2**	**8.6**	**9.0**	**9.3**	**9.7**	**10**	**10**	**11**	**11**	**12**
b. Wastewater Handling	**6.8**	**7.0**	**7.2**	**7.3**	**7.5**	**7.7**	**7.8**	**7.8**	**7.8**	**7.8**	**7.9**	**8.0**	**8.1**	**8.2**
c. Waste Incineration	–	–	–	–	–	–	–	–	–	–	–	–	–	-

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

Totals may not add due to rounding.

TABLE A12-25: 2003 Greenhouse Gas Emissions Summary for Northwest Territories and Nunavut

	Greenhouse Gases								
GHG Source Category	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	TOTAL
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**1520**	**7.9**	**170**	**0.22**	**67**	**–**	**–**	**–**	**1760**
ENERGY	**1520**	**7**	**100**	**0.2**	**60**	**–**	**–**	**–**	**1730**
a. Stationary Combustion Sources	**711**	**0.7**	**10**	**0.03**	**10**	**–**	**–**	**–**	**736**
Electricity and Heat Generation	216	0.01	0.17	0.02	7	–	–	–	223
Fossil Fuel Industries	140	0.4	9	0.00	1	–	–	–	150
Mining	90.0	0.00	0.01	0.00	0.4	–	–	–	90.5
Manufacturing Industries	0.08	0.00	0.00	0.00	0.0	–	–	–	0.07
Construction	1.41	0.00	0.00	0.00	0.0	–	–	–	1.42
Commercial & Institutional	159	0.00	0.05	0.00	1	–	–	–	160
Residential	87.1	0.2	5	0.00	1	–	–	–	93
Agriculture & Forestry	15.6	0.00	0.00	0.00	0.05	–	–	–	15.7
b. Transportation	**786**	**0.07**	**2**	**0.2**	**50**	**–**	**–**	**–**	**840**
Domestic Aviation	133	0.01	0.3	0.01	4	–	–	–	140
Road Transportation	287	0.02	0.41	0.02	6.2	–	–	–	294
Light-Duty Gasoline Vehicles	38.8	0.00	0.07	0.01	1.6	–	–	–	40.5
Light-Duty Gasoline Trucks	34.7	0.00	0.09	0.01	2.4	–	–	–	37.2
Heavy-Duty Gasoline Vehicles	6.45	0.00	0.02	0.00	0.30	–	–	–	6.76
Motorcycles	0.21	0.00	0.00	0.00	0.00	–	–	–	0.21
Light-Duty Diesel Vehicles	0.58	0.00	0.00	0.00	0.01	–	–	–	0.59
Light-Duty Diesel Trucks	2.13	0.00	0.00	0.00	0.05	–	–	–	2.18
Heavy-Duty Diesel Vehicles	203	0.01	0.2	0.01	2	–	–	–	205
Propane & Natural Gas Vehicles	1.72	0.00	0.01	0.00	0.01	–	–	–	1.7
Railways	2.55	0.00	0.00	0.00	0.3	–	–	–	3
Domestic Marine	–	–	–	–	–	–	–	–	–
Others	360	0.04	0.9	0.1	40	–	–	–	400
Off-Road Gasoline	20	0.02	0.5	0.00	0.1	–	–	–	20
Off-Road Diesel	340	0.02	0.4	0.1	40	–	–	–	400
Pipelines	2.87	0.00	0.00	0.0	0.1	–	–	–	3.01
c. Fugitive Sources	**21**	**6.3**	**130**	**–**	**–**	**–**	**–**	**–**	**153**
Coal Mining	–	–	–	–	–	–	–	–	–
Oil and Natural Gas	21	6.3	130	–	–	–	–	–	153
INDUSTRIAL PROCESSES	**5.38**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**5.38**
a. Mineral Production[1]	–	–	–	–	–	–	–	–	–
Cement	–	–	–	–	–	–	–	–	–
Lime	–	–	–	–	–	–	–	–	–
b. Chemical Industry[2]	–	–	–	–	–	–	–	–	–
Nitric Acid Production	–	–	–	–	–	–	–	–	–
Adipic Acid Production	–	–	–	–	–	–	–	–	–
c. Metal Production	–	–	–	–	–	–	–	–	–
Iron and Steel Production	–	–	–	–	–	–	–	–	–
Aluminium Production	–	–	–	–	–	–	–	–	–
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	–	–	–	–
d. Consumption of Halocarbons and SF_6[1]	–	–	–	–	–	–	–	–	–
e. Other & Undifferentiated Production[2]	**5.4**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**5.4**
SOLVENT & OTHER PRODUCT USE	**–**	**–**	**–**	**0.00**	**1.1**	**–**	**–**	**–**	**1.1**
AGRICULTURE	–	–	–	–	–	–	–	–	–
a. Enteric Fermentation	–	–	–	–	–	–	–	–	–
b. Manure Management	–	–	–	–	–	–	–	–	–
c. Agricultural Soils	–	–	–	–	–	–	–	–	–
Direct Sources	–	–	–	–	–	–	–	–	–
Indirect Sources	–	–	–	–	–	–	–	–	–
WASTE	**–**	**0.84**	**18**	**0.01**	**2**	**–**	**–**	**–**	**20**
a. Solid Waste Disposal on Land	**–**	**0.55**	**12**	**–**	**–**	**–**	**–**	**–**	**12**
b. Wastewater Handling	**–**	**0.29**	**6.0**	**0.01**	**2**	**–**	**–**	**–**	**8.2**
c. Waste Incineration	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**

Notes:

[1] Emissions associated with the use of HFCs, PFCs, limestone, and soda ash are reported in the national Industrial Processes total.

[2] Ammonia production emissions are included under undifferentiated production at the provincial level.

Totals may not add due to rounding.

ANNEX 13: EMISSION FACTORS

This annex summarizes the development and selection of emission factors used to prepare the national GHG inventory.

A13.1 FUEL COMBUSTION

A13.1.1 NATURAL GAS AND NGLs (STATIONARY SOURCES)

A13.1.1.1 Carbon Dioxide (CO_2)

CO_2 emission factors for fossil fuel combustion are primarily dependent on the properties of the fuel and, to a lesser extent, the combustion technology.

For natural gas, there are two major qualities of fuels combusted in Canada: marketable fuel (processed) and non-marketable fuel (unprocessed). Emission factors have been developed for these two categories (Table A13-1) based on data from the chemical analysis of representative natural gas samples (McCann, 2000) and an assumed fuel combustion efficiency of 99.5% (IPCC/OECD/IEA, 1997). The emission factor for marketable fuel matches closely with previous factors based on energy contents reported in the RESD (Jaques, 1992). The factor for non-marketable natural gas is higher than that for marketable fuels due to its raw nature, which results in higher levels of NGLs in the fuel.

NGL (ethane, propane, butane) emission factors were developed based on chemical analysis data for marketable fuels (McCann, 2000) and an assumed fuel combustion efficiency of 99.5% (IPCC/OECD/IEA, 1997). The emission factors are lower than those developed on the assumption of pure fuels (Jaques, 1992) due to the presence of impurities in the fuels.

A13.1.1.2 Methane (CH_4)

Emissions of CH_4 from fuel combustion are technology dependent. Sectoral emission factors (Table A13-1) have been developed based on technologies typically used in Canada. The factors were developed based on a review of emission factors for combustion technologies and an analysis of combustion technologies (SGA, 2000). The emission factor for the producer consumption of natural gas was developed based on a technology split for the upstream oil and gas industry (CAPP, 1999) and technology-specific emission factors from the U.S. EPA report AP-42 (EPA, 1996).

A13.1.1.3 Nitrous Oxide (N_2O)

Emissions of N_2O from fuel combustion are technology dependent. Emission factors for sectors (Table A13-1) have been developed based on technologies typically used in Canada. The factors were developed from a review of emission factors for and an analysis of combustion technologies (SGA, 2000).

TABLE A13-1: Emission Factors for Natural Gas and NGLs (Energy Stationary Combustion Sources)

	Emission Factors		
Source	CO_2	CH_4	N_2O
Natural Gas	**g/m³**	**g/m³**	**g/m³**
Electric Utilities	1891[1]	0.49[2]	0.049[2]
Industrial	1891[1]	0.037[2]	0.033[2]
Producer Consumption	2389[1]	6.5[3,4]	0.06[2]
Pipelines	1891[1]	1.9[2]	0.05[2]
Residential, Commercial, Agriculture	1891[1]	0.037[2]	0.035[2]
Natural Gas Liquids	**g/L**	**g/L**	**g/L**
Ethane	976[1]	N/A	N/A
Propane	1500[1]	0.024[2]	0.108[2]
Butane	1730[1]	0.024[2]	0.108[2]

Notes:

1 Adapted from McCann (2000).

2 SGA (2000).

3 EPA (1996).

4 CAPP (1999).

A13.1.2 REFINED PETROLEUM PRODUCTS (STATIONARY COMBUSTION SOURCES)

A13.1.2.1 Carbon Dioxide (CO_2)

CO_2 emission factors for fossil fuel combustion are primarily dependent on the properties of the fuel and, to a lesser extent, the combustion technology.

Emission factors have been developed for each major class of refined petroleum product (Table A13-2) based on standard fuel properties and an assumed fuel combustion efficiency of 99.0% (Jaques, 1992).

The composition of petroleum coke is process specific. Factors have been developed for both coker-derived and catalytic cracker-derived cokes. Average factors have been developed based on data provided by industry (Nyboer, 1996). Industry factors were provided by industry on a mass basis and were converted to a volumetric basis for comparability with the national energy data using the density of coke provided by Statistics Canada (#57-003).

A13.1.2.2 Methane (CH_4)

Emissions of CH_4 from fuel combustion are technology dependent. Emission factors for sectors have been developed (Table A13-2) based on technologies typically used in Canada. The factors were developed from a review of emission factors for and an analysis of combustion technologies (SGA, 2000).

An emission factor for petroleum coke could not be found in the literature due to a lack of research in this area. It was assumed to be the same as that for heavy fuel oil used in industry.

An emission factor for refinery fuel gas (still gas) is not available according to the SGA (2000) study.

A13.1.2.3 Nitrous Oxide (N_2O)

Emissions of N_2O from fuel combustion are technology dependent. Emission factors for sectors have been developed (Table A13-2) based on technologies typically used in Canada. The factors were developed from a review of emission factors for and an analysis of combustion technologies (SGA, 2000).

An emission factor for petroleum coke could not be found, so it was assumed to be the same as that for heavy fuel oil used in industry.

TABLE A13-2: Emission Factors for Refined Petroleum Products (Energy Stationary Combustion Sources)

		Emission Factors	
Source	CO_2	CH_4	N_2O
Light Fuel Oil	**g/L**	**g/L**	**g/L**
Electric Utilities	2830[1]	0.18[2]	0.031[2]
Industry	2830[1]	0.006[2]	0.031[2]
Producer Consumption	2830[1]	0.006[2]	0.031[2]
Residential	2830[1]	0.026[2]	0.006[2]
Other Small Combustion	2830[1]	0.026[2]	0.031[2]
Heavy Fuel Oil	**g/L**	**g/L**	**g/L**
Electric Utilities	3090[1]	0.034[2]	0.064[2]
Industry	3090[1]	0.12[2]	0.064[2]
Producer Consumption	3090[1]	0.12[2]	0.064[2]
Residential, etc.	3090[1]	0.057[2]	0.064[2]
Kerosene	**g/L**	**g/L**	**g/L**
Electric Utilities	2550[1]	0.006[2]	0.031[2]
Industry	2550[1]	0.006[2]	0.031[2]
Producer Consumption	2550[1]	0.006[2]	0.031[2]
Residential, etc.	2550[1]	0.026[2]	0.006[2]
Other Small Combustion	2550[1]	0.026[2]	0.031[2]
Diesel	**g/L**	**g/L**	**g/L**
Electric Utilities	2730[1]	0.133[2]	0.4[2]
Producer Consumption	2730[1]	0.133[2]	0.4[2]
Petroleum Coke	**g/L**	**g/L**	**g/L**
Petroleum Coke Others	4200[3]	0.12[2]	0.064[2]
Producer Consumption	4200[3]	0.12[2]	0.064[2]
Coke from Catalytic Crackers	3800[3]	0.12[2]	0.064[2]
	g/m^3	**g/m^3**	**g/m^3**
Still Gas	2000[1]	0.037[2]	0.002[2]

Notes:
1 Jaques (1992).
2 SGA (2000).
3 Nyboer (1996).

A13.1.3 COAL AND COAL PRODUCTS (STATIONARY COMBUSTION SOURCES)

A13.1.3.1 Carbon Dioxide (CO_2)

CO_2 emission factors for coal combustion are dependent on the properties of the fuel and, to a lesser extent, the combustion technology.

Coal emission factors (Table A13-3) have been developed for each province based on the rank of the coal and the region of supply. Emission factors have been developed based on data from chemical analysis of coal samples for electric utilities, which comprise the vast majority of coal consumption, and a fuel combustion efficiency of 99.0% (Jaques, 1992). The factors for coal were reviewed in 1999 because the supply and quality of coal used may change over time. Based on this review, it was determined that updated factors should be used for the more recent years. The factors for the period 1990 are based on supply and quality data from 1988 (Jaques, 1992). For 1998 to the present, factors are based on 1998 coal quality and supply (McCann, 2000). The factors for 1991–1997 are based on both studies. In order to address the change in emission factors introduced by the 2000 study, a linear interpolation method was used to derive coal-specific emission factors for 1991–1997 using the 1990 (Jaques, 1992) and 1998 (McCann, 2000) emission factors as the endpoints.

Coke and coke oven gas emission factors were developed based on industry data (Jaques, 1992).

A13.1.3.2 Methane (CH_4)

Emissions of CH_4 from fuel combustion are technology dependent. Emission factors for sectors (Table A13-4) have been developed based on technologies typically used in Canada. The factors were developed from a review of emission factors for and an analysis of combustion technologies (SGA, 2000).

A13.1.3.3 Nitrous Oxide (N_2O)

Emissions of N_2O from fuel combustion are technology dependent. Emission factors for sectors (Table A13-4) have been developed based on technologies typically used in Canada. The factors were developed from a review of emission factors for and an analysis of combustion technologies (SGA, 2000).

A13.1.4 MOBILE COMBUSTION

A13.1.4.1 Carbon Dioxide (CO_2)

CO_2 emission factors for mobile combustion are dependent on fuel properties and are the same as those used for stationary combustion for all fuels (Table A13-5).

A13.1.4.2 Methane (CH_4)

Emissions of CH_4 from fuel combustion are technology dependent. Emission factors for sectors have been developed (Table A13-5) based on technologies typically used in Canada. The factors were developed from a review of emission factors for and an analysis of combustion technologies (SGA, 2000).

A13.1.4.3 Nitrous Oxide (N_2O)

Emissions of N_2O from fuel combustion are technology dependent. Emission factors for sectors have been developed (Table A13-5) based on technologies typically used in Canada. The factors were developed from a review of emission factors for and an analysis of combustion technologies (SGA, 2000).

TABLE A13-3: CO_2 Emission Factors for Coal and Coal Products (Energy Stationary Combustion Sources)

Province	CO_2 Emission Factors								
Coals	1990	1991	1992	1993	1994	1995	1996.	1997	1998–2003
					g/kg				
Newfoundland and Labrador									
Canadian Bituminous[3]	2300[1]	2294	2287	2281	2274	2268	2262	2255	2249[2]
Anthracite	2390[1]	2390	2390	2390	2390	2390	2390	2390	2390[2]
Prince Edward Island									
Canadian Bituminous[3]	2300[1]	2294	2287	2281	2274	2268	2262	2255	2249[2]
Nova Scotia									
Canadian Bituminous	2300[1]	2294	2287	2281	2274	2268	2262	2255	2249[2]
U.S. Bituminous	2330[1]	2325	2320	2314	2309	2304	2299	2293	2288[2]
New Brunswick									
Canadian Bituminous	2230[1]	2201	2172	2142	2113	2084	2055	2026	1996[2]
U.S. Bituminous	2500[1]	2476	2453	2429	2405	2382	2358	2334	2311[2]
Quebec									
Canadian Bituminous[3]	2300[1]	2294	2287	2281	2274	2268	2262	2255	2249[2]
U.S. Bituminous	2500[1]	2480	2461	2441	2421	2402	2382	2362	2343[2]
Anthracite	2390[1]	2390	2390	2390	2390	2390	2390	2390	2390[2]
Ontario									
Canadian Bituminous	2520[1]	2487	2454	2420	2387	2354	2321	2287	2254[2]
U.S. Bituminous	2500[1]	2492	2483	2475	2466	2458	2449	2441	2432[2]
Sub-Bituminous[6]	2520[1]	2422	2323	2225	2126	2028	1930	1831	1733[2]
Lignite	1490[1]	1488	1486	1485	1483	1481	1479	1478	1476[2]
Anthracite	2390[1]	2390	2390	2390	2390	2390	2390	2390	2390[2]
Manitoba									
Canadian Bituminous	2520[1]	2486	2453	2419	2386	2352	2319	2285	2252[2]
U.S. Bituminous[5]					2387	2387			
Sub-Bituminous	2520[1]	2422	2323	2225	2126	2028	1930	1831	1733[2]
Lignite	1520[1]	1508	1496	1484	1472	1460	1448	1436	1424[2]
Anthracite	2390[1]	2390	2390	2390	2390	2390	2390	2390	2390[2]
Saskatchewan									
Canadian Bituminous[4]	1700[1]	1719	1738	1757	1776	1795	1814	1833	1852[2]
Sub-Bituminous[5]					1747	1747			
Lignite	1340[1]	1351	1362	1373	1384	1394	1405	1416	1427[2]
Alberta									
Canadian Bituminous	1700[1]	1719	1738	1757	1776	1795	1814	1833	1852[2]
Sub-Bituminous	1740[1]	1743	1746	1749	1753	1756	1759	1762	1765[2]
Anthracite	2390[1]	2390	2390	2390	2390	2390	2390	2390	2390[2]
British Columbia									
Canadian Bituminous	1700[1]	1747	1793	1840	1886	1933	1979	2026	2072[2]
All Provinces									
Metallurgical Coke	2480[1]	2480	2480	2480	2480	2480	2480	2480	2480[2]
					g/m³				
Coke Oven Gas	1600[1]	1600	1600	1600	1600	1600	1600	1600	1600[2]

Notes:

1 Jaques (1992).

2 Adapted from McCann (2000).

3 Assumed same source of Canadian bituminous for Newfoundland and Labrador, Prince Edward Island, Nova Scotia, and Quebec.

4 Assumed same source of Canadian bituminous for Saskatchewan and Alberta.

5 Used Canada weighted average for 1990.

6 Represents both domestic and imported sub-bituminous.

TABLE A13-4: CH_4 and N_2O Emission Factors for Coals

Source	CH_4 g/kg	N_2O g/kg
Electric Utilities	0.022[1]	0.032[1]
Industry	0.03[1]	0.02[1]
Residential	4[1]	0.02[1]
Metallurgical Coke	0.03[1]	0.02[1]
	g/m^3	g/m^3
Coke Oven Gas	0.037[1]	0.035[1]

Note:
1 SGA (2000).

A13.2 FUGITIVE EMISSION FACTORS: COAL MINING

Fugitive emissions from coal mining are predominantly CH_4. These emissions result from the release of entrained CH_4 from coal formation during mining. The emission factors have been developed (Table A13-6) based on mine-specific and basin-specific data (King, 1994). The development of the factors is described in the fugitive emissions section (Section 3.2) of the inventory report.

TABLE A13-5: Emission Factors for Energy Mobile Combustion Sources

	Emission Factors		
Use	CO_2 g/L fuel	CH_4 g/L fuel	N_2O g/L fuel
On-Road Transport			
Gasoline Vehicles			
Light-Duty Gasoline Vehicles (LDGVs)			
- Tier 1, Three-Way Catalyst	2360[1]	0.12[2]	0.26[2]
- Tier 0, New Three-Way Catalyst	2360[1]	0.32[2]	0.25[2]
- Tier 0, Aged Three-Way Catalyst	2360[1]	0.32[2]	0.58[2]
- Oxidation Catalyst	2360[1]	0.42[2]	0.2[2]
- Non-Catalyst	2360[1]	0.52[2]	0.028[2]
Light-Duty Gasoline Trucks (LDGTs)			
- Tier 1, Three-Way Catalyst	2360[1]	0.22[2]	0.41[2]
- Tier 0, New Three-Way Catalyst	2360[1]	0.41[2]	0.45[2]
- Tier 0, Aged Three-Way Catalyst	2360[1]	0.41[2]	1[2]
- Oxidation Catalyst	2360[1]	0.44[2]	0.2[2]
- Non-Catalyst	2360[1]	0.56[2]	0.028[2]
Heavy-Duty Gasoline Vehicles (HDGVs)			
- Three-Way Catalyst	2360[1]	0.17[2]	1[2]
- Non-Catalyst	2360[1]	0.29[2]	0.046[2]
- Uncontrolled	2360[1]	0.49[2]	0.08[2]
Motorcycles			
- Non-Catalytic Controlled	2360[1]	1.4[2]	0.046[2]
- Uncontrolled	2360[1]	2.3[2]	0.046[2]
Diesel Vehicles			
Light-Duty Diesel Vehicles (LDDVs)			
- Advance Control	2730[1]	0.05[2]	0.2[2]
- Moderate Control	2730[1]	0.07[2]	0.2[2]
- Uncontrolled	2730[1]	0.1[2]	0.2[2]
Light-Duty Diesel Trucks (LDDTs)			
- Advance Control	2730[1]	0.07[2]	0.2[2]
- Moderate Control	2730[1]	0.07[2]	0.2[2]
- Uncontrolled	2730[1]	0.08[2]	0.2[2]
Heavy-Duty Diesel Vehicles (HDDVs)			
- Advance Control	2730[1]	0.12[2]	0.08[2]
- Moderate Control	2730[1]	0.13[2]	0.08[2]
- Uncontrolled	2730[1]	0.15[2]	0.08[2]
Natural Gas Vehicles	1.89[3]	0.022[2]	6E-05[2]
Propane Vehicles	1500[3]	0.52[2]	0.028[2]
Off-Road Vehicles			
Other Gasoline Vehicles	2360[1]	2.7[2]	0.05[2]
Other Diesel Vehicles	2730[1]	0.14[2]	1.1[2]
Diesel Rail Transportation	2730[1]	0.15[2]	1.1[2]
Marine Transportation			
Gasoline Boats	2360[1]	1.3[2]	0.06[2]
Diesel Ships	2730[1]	0.15[2]	1.00[2]
Light Fuel Oil Ships	2830[1]	0.3[2]	0.07[2]
Heavy Fuel Oil Ships	3090[1]	0.3[2]	0.08[2]
Air Transportation			
Conventional Aircraft	2330[1]	2.19[2]	0.23[2]
Jet Aircraft	2550[1]	0.08[2]	0.25[2]

Notes:
1 Jaques (1992).
2 SGA (2000).
3 Adapted from McCann (2000).

TABLE A13-6: Emission Factors for Fugitive Sources — Coal Mining

Province	Method	Coal Type	Emission Factors *t CH_4/kt coal*
Nova Scotia	Underground	Bituminous	13.79
Nova Scotia	Surface	Bituminous	0.13
New Brunswick	Surface	Bituminous	0.13
Saskatchewan	Surface	Lignite	0.06
Alberta	Surface	Bituminous	0.45
Alberta	Underground	Bituminous	1.76
Alberta	Surface	Sub-Bituminous	0.19
British Columbia	Surface	Bituminous	0.58
British Columbia	Underground	Bituminous	4.1

Source: Adapted from King (1994).

A13.3 INDUSTRIAL PROCESSES

A13.3.1 MINERAL, CHEMICAL, AND METAL INDUSTRIES

Emissions from industrial processes are process and technology specific. The development of the factors for each source (Table A13-7) is described in the Industrial Processes section of the inventory report.

A13.3.2 CONSUMPTION OF HALOCARBONS

The use of HFCs in AC, refrigeration, aerosols, foam blowing, and total flooding systems can result in HFC emissions. The emission factors used to estimate HFC emissions in 1995 are given in Table A13-8.

TABLE A13-7: Emission Factors for Industrial Process Sources

Source	Description	Emission Factors			
		CO_2	N_2O	CF_4	C_2F_6
Mineral Use			**g/kg feed**		
Limestone Use	In iron and steel, glass, non-ferrous metal production	440	–	–	–
Soda Ash Use	In glass manufacturing	415	–	–	–
Mineral Products			**g/kg product**		
Cement Production	Limestone calcination	507	–	–	–
Lime Production	Limestone calcination (high-calcium lime)	750	–	–	–
	Limestone calcination (dolomitic lime)	860	–	–	–
Chemical Industry			**kg/t product**		
Ammonia Production	From natural gas reforming, which produces the hydrogen needed	1560	–	–	–
Nitric Acid Production	Plants with catalytic converters	–	0.66	–	–
	Plants with extended absorption for NO_x (type 1)	–	9.4	–	–
	Plants with extended absorption for NO_x (type 2)	–	12	–	–
			kg/kg product		
Adipic Acid Production	Plants without abatement	–	0.303	–	–
Metal Production			**kg/t product**		
Primary Aluminium	Electrolysis process — cell technology				
	Side-worked pre-baked	1600	–	1.4	0.336
	Centre-worked pre-baked	1600	–	0.2–0.4	0.034–0.068
	Horizontal stud Søderberg	1700	–	0.6–0.7	0.054–0.063
	Vertical stud Søderberg	1700	–	0.4–0.6	0.024–0.036
			g/kg feed (coke)		
Iron and Steel Production		2479	–	–	–

Sources:

CO_2 Emission Factors:

Limestone Use — ORTECH Corporation (1994).
Soda Ash Use — DOE/EIA (1993).
Lime Production — IPCC (2000).
Cement Production — IPCC/OECD/IEA (1997).
Ammonia Production — Faith et al. (1975); Jaques (1992).
Primary Aluminium Production — AAC (2002).
Iron and Steel — Jaques (1992).

N_2O Emission Factors:

Nitric Acid — Collis (1992).
Adipic Acid Production — Thiemens and Trogler (1991).

CF_4 and C_2F_6 Emission Factors:

Primary Aluminium Production — AAC (2002).

TABLE A13-8: Emission Factors for Consumption of HFCs

Application	Emission Factors *kg loss/kg consumed*
Aerosols	1
Foams	0.04
AC OEM	1
AC Service	0.1
Refrigeration	0.35
Total Flooding Systems	0.35

Source: IPCC/OECD/IEA (1997).

A13.3.3 NON-ENERGY USE OF FOSSIL FUELS

A13.3.3.1 Carbon Dioxide (CO_2)

The use of fossil fuels as feedstocks or for other non-energy uses may result in emissions during the life of manufactured products. Industry-average emission factors (Table A13-9) have been developed based on the total potential CO_2 emission rates (McCann, 2000) and the IPCC default percentages of carbon stored in products (IPCC/OECD/IEA, 1997).

TABLE A13-9: Emission Factors for Hydrocarbon Non-Energy Products

Description	CO_2 Emission Factor *g/L feedstock*
Ethane Use	197
Butane Use	349
Propane Use	303
Petrochemical Distillate Use for Feedstocks	500
Naphtha Used for Various Products	625
Petroleums Used for Lubricants	1410
Petroleums Used for Other Products	1450
	g/m^3
Natural Gas Used for Chemical Products	1267

Sources: IPCC/OECD/IEA (1997); McCann (2000).

A13.4 SOLVENT AND OTHER PRODUCT USE

N_2O emissions can result from its use as an anaesthetic and propellant. The development of the emission factors shown in Table A13-10 is described in the Solvent and Other Product Use section of the inventory report.

TABLE A13-10: Solvent and Other Product Emission Factors

Product	Application	Emission Factors *N_2O g/capita*
N_2O Use	Anaesthetic Usage	46.2
	Propellant Usage	2.38

Source: N_2O Emission Factors: Anaesthetic Usage — W. Fettes (personal communication, 1994).

A13.5 AGRICULTURE

Emissions from agriculture result from enteric fermentation, land management, and manure management. Methodologies for generating these emission estimates (Table A13-11 to Table A13-16) are detailed in Annex 3.

TABLE A13-11: CH_4 Emission Factors for Livestock and Manure

	Emission Factors	
Animal Type	**Enteric Fermentation** *kg CH_4/head per year*	**Manure Management** *kg CH_4/head per year*
Cattle		
Bulls	94^{1}	10.8^{3}
Dairy Cows	126^{1}	32.5^{3}
Beef Cows	90^{1}	3.4^{3}
Dairy Heifers	73^{1}	17.8^{3}
Beef Heifers	75^{1}	2.4^{3}
Heifers for Slaughter	63^{1}	2.0^{3}
Steers	56^{1}	2.0^{3}
Calves	40^{1}	0.98^{3}
Pigs		
Swine	1.5^{2}	7.7^{3}
Other Livestock		
Sheep	8^{2}	0.36^{3}
Lambs	8^{2}	0.21^{3}
Goats	5^{2}	0.22^{3}
Horses	18^{2}	2.1^{3}
Buffalo	55^{2}	2.0^{3}
Poultry		
Chickens	Not Estimated	0.02^{3}
Hens	Not Estimated	0.13^{3}
Turkeys	Not Estimated	0.02^{3}

Sources:

1 Sources of emission factors (Tier 2) are country specific (Boadi et al., 2004).

2 Source of emission factors is IPCC/OECD/IEA (1997).

3 Sources of emission factors (Tier 2) are country specific (Marinier et al., 2004).

TABLE A13-12: Nitrogen Excretion for Each Specific Animal Type

Animal Type	Nitrogen Excretion *kg N/head per year*
Non-Dairy Cattle	44.7
Dairy Cattle	105.2
Poultry	0.36
Sheep and Lambs	4.1
Swine	11.6
Other (Goats, Horses, and Buffaloes)	49.3

Source: ASAE (1999).

TABLE A13-13: Percentage of Manure Nitrogen Produced by AWMS in North America

Animal Type	Liquid Systems	Solid Storage and Drylot	Pasture and Paddock	Other Systems
Non-Dairy Cattle	1	47	48	4
Dairy Cattle	42	40	18	0
Poultry	10	88	2	0
Sheep and Lambs	0	38	62	0
Swine	96	3	0	1
Other (Goats, Horses, and Buffaloes)	0	42	58	0

Source: Mannier et al. (2004).

TABLE A13-14: Percentage of Manure Nitrogen Lost as N_2O for Specific AWMS

Animal Type	Liquid Systems	Solid Storage and Drylot	Pasture and Paddock	Other Systems
Non-Dairy Cattle	0.1	2.0	2.0	0.5
Dairy Cattle	0.1	2.0	2.0	0.5
Poultry	0.1	2.0	2.0	0.5
Sheep and Lambs	0.1	2.0	2.0	0.5
Swine	0.1	2.0	2.0	0.5
Other (Goats and Horses)	0.1	2.0	2.0	0.5

Source: IPCC/OECD/IEA (1997).

TABLE A13-15: Dry Matter Fraction of Various Crops[1]

Specific Crop Type	Dry Matter Fraction
Wheat	0.86
Barley	0.86
Corn	0.86
Oats	0.86
Rye	0.86
Mixed Grains	0.86
Flax Seed	0.86
Canola	0.86
Buckwheat	0.86
Mustard Seed	0.86
Sunflower Seed	0.86
Canary Seed	0.86
Tame Hay	0.86
Fodder Corn	0.30[2]
Sugar Beets	0.20[2]
Dry Peas	0.86
Soya Beans	0.86
Lentils	0.86
Field Beans	0.86
Potatoes	0.25[2]

Notes:

1 Unless otherwise specified, data are from IPCC/OECD/IEA (1997).

2 Sources of data are expert opinion.

A13.6 BIOMASS COMBUSTION

A13.6.1 CARBON DIOXIDE (CO_2)

Emissions of CO_2 from the combustion of biomass (whether for energy use, from prescribed burning, or from wildfires) are not included in national inventory totals. These emissions are estimated and recorded as a loss of biomass stock in the LULUCF Sector.

The emissions related to energy use are reported as memo items in the CRF as required by the UNFCCC. Emissions from this source are primarily dependent on the characteristics of the fuel being combusted. The methodology for deriving the emission factors (Table A13-17) is described in the biomass combustion section of the inventory report (see Section 3.3.2).

CO_2 emissions from prescribed burning are included in the emissions from the on-site natural decay of post-harvest residues (slash) in the LULUCF section. The carbon emitted as CO_2 during forest fires is considered in the forest carbon balance.

A13.6.2 METHANE (CH_4)

Emissions of CH_4 from fuel combustion are technology dependent. The emission factors (Table A13-17) were derived from a review of emission factors for combustion technologies (SGA, 2000). The factors are from the U.S. EPA AP-42 Supplement B (EPA, 1996).

CH_4 emissions from prescribed burns and wildfires are obtained from the estimated average fuel consumptions (kt biomass/ha) and the emission factors (g/kg biomass consumed). Emission factors for both prescribed burns and wildfires were taken from Taylor and Sherman (1996). See Section A3.2 in Annex 3 for more details.

A13.6.3 NITROUS OXIDE (N_2O)

Emissions of N_2O from fuel combustion are technology dependent. The emission factors (Table A13-17) were developed from a review of emission factors for combustion technologies and an analysis of combustion technologies typically used in Canada (SGA, 2000). The factors are from the U.S. EPA AP-42 Supplement B (EPA, 1996).

N_2O emissions from prescribed burns and wildfires are obtained from the estimated average fuel consumptions (kt biomass/ha) and the emission factors (g/kg biomass consumed). Emission factors for both prescribed burns and wildfires were taken from Taylor and Sherman (1996). See Section A3.2 for more details.

TABLE A13-16: IPCC Default Emission Factors and Parameters[1]

Emission Process	Emission Factors
Synthetic Fertilizer Nitrogen	0.0125 kg N_2O-N/kg N
Biological Nitrogen Fixation	0.0125 kg N_2O-N/kg N
Animal Waste Applied as Fertilizers	0.0125 kg N_2O-N/kg N
Crop Residue Decomposition	0.0125 kg N_2O-N/kg N
Cultivation of Histosols	8 kg N_2O-N/ha per year
Volatilization and Redeposition of Nitrogen	0.01 kg N_2O-N/kg N
Leaching and Runoff of Nitrogen	0.025 kg N_2O-N/kg N
	Parameters
Fraction of Fertilizer Nitrogen Available to Volatilization as NH_3 and NO_x	0.1 kg N/kg N
Fraction of Manure Nitrogen Available to Volatilization as NH_3 and NO_x	0.2 kg N/kg N
Fraction of Manure and Fertilizer Nitrogen Available to Leaching and Runoff	0.15 kg N/kg N[2]
Fraction of Nitrogen Contained in Legume Crops	0.03 kg N/kg dry mass
Fraction of Nitrogen Contained in Non-Legume Crops	0.015 kg N/kg dry mass
Fraction of Tame Hay Assumed to Be Alfalfa	0.60[2]

Notes:

1 Unless otherwise specified, emission factors or parameters are from IPCC/OECD/IEA (1997).

2 Sources of parameters are country specific.

TABLE A13-17: Biomass Emission Factors

		Emission Factors		
Source	**Description**	CO_2 *g/kg fuel*	CH_4 *g/kg fuel*	N_2O *g/kg fuel*
Wood Fuel/Wood Waste	Industrial combustion	950	0.05	0.02
Forest Fires	Open combustion	1630	3	1.75
Prescribed Burns	Open combustion	1620	6.2	1.3
Spent Pulping Liquor	Industrial combustion	1428	0.05	0.02
Stoves and Fireplaces	Residential combustion			
Conventional Stoves		1500	15	0.16
Conventional Fireplaces and Inserts		1500	15	0.16
Stoves/Fireplaces with Advanced Technology or Catalytic Control		1500	6.9	0.16
Other Wood-Burning Equipment		1500	15	0.16

Sources:

CO_2 Emission Factors:

Wood Fuel/Wood Waste — EPA (1996).

Accidental Forest Fires and Prescribed Burns — Taylor and Sherman (1996).

CH_4 Emission Factors:

Wood Fuel/Wood Waste — EPA (1985).

Accidental Forest Fires and Prescribed Burns — Taylor and Sherman (1996).

N_2O Emission Factors:

Wood Fuel/Wood Waste — Rosland and Steen (1990); Radke et al. (1991).

Accidental Forest Fires and Prescribed Burns — Taylor and Sherman (1996).

Note:

CO_2 emissions from biomass sources are not included in inventory totals. CH_4 and N_2O emissions are inventoried under Energy, except for accidental forest fires and prescribed burns, which are reported under Land Use, Land-Use Change and Forestry.

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ANNEX 14: ROUNDING PROTOCOL

A rounding protocol has been developed for the emission and removal estimates in order to provide context on their uncertainty levels. The accuracy of the data is reflected by presenting the emission and removal estimates to the appropriate number of significant figures based on the uncertainty of the specific category. The number of significant figures that each emission source and sink category has been rounded to can be found in Table A14-1. The uncertainty intervals that were used for each source category were developed using the Monte Carlo method by ICF Consulting (ICF, 2004, 2005) based on the 2001 inventory (as submitted in 2003 to the UNFCCC Secretariat), published uncertainty estimates (IPCC/OECD/IEA, 1997; IPCC, 2001), and expert opinion. The uncertainty interval for SF_6 emissions in the category Consumption of Halogens and SF_6 was taken from the study *Improving and Updating Industrial Process-Related Activity Data and Methodologies Used in Canada's Greenhouse Gas Inventory* by Cheminfo Services (2005). For a fuller description of the analysis of uncertainty in Canada's emission estimates, refer to Annex 7.

The following uncertainty interval values have been used to determine the significant number of figures to which the estimates have been rounded (Neitzert, 1999):

- One significant figure: equal to and greater than 50%;
- Two significant figures: between 10% and 50%; and
- Three significant figures: equal to and less than 10%.

The LULUCF Sector has not been formally assessed for uncertainty — new methodologies, which were not available for the 2004 ICF study, have been used to develop the estimates for the 2005 UNFCCC submission. For this sector, the number of significant figures for each category was determined by expert opinion. Some other categories are presented in the summary tables because they represent aggregations of interest, but have also not been assessed for uncertainty because they do not represent standard IPCC categories. In these cases, the number of significant figures has been estimated on the basis of similarity with other categories whose uncertainty has been assessed.

In the ICF study, the uncertainty intervals established were based on the original, raw gas estimates and did not take into consideration the GWP uncertainties when CO_2 equivalent values were calculated. There was one exception — the case of the total CO_2 equivalent estimate for Canada. This uncertainty interval, including GWP uncertainty, was determined to be -5% to 10%. When the GWP uncertainty was not taken into consideration, the uncertainty interval was determined to be -3% to 6%. Although the GWP uncertainty does affect the uncertainty associated with Canada's total GHG emission estimate, it does not have an impact on the associated number of significant figures.

Since the effect of GWP uncertainties on individual category estimates has not been determined, the number of significant figures shown for the CO_2 equivalent estimates have been left the same as those for the individual gas estimates without the GWPs.

Uncertainties have been determined for the national emission estimates, as required by Good Practice Guidance, but not for provincial emission estimates. As there are no uncertainties established for provincial estimates, the rounding protocol used for the national emission tables has been applied to the provincial emission tables.

All calculations, including summing of emission totals, have been made using unrounded data. The rounding protocol has been applied to the estimates only after the calculations have been completed. Therefore, individual values in the tables may not add up to the subtotals and/or overall totals.

TABLE A14-1: Number of Significant Figures Applied to GHG Summary Tables

GHG Source/Sink Categories	Greenhouse Gases CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	TOTAL
TOTAL	3	2	2	2	3	2	3
ENERGY	3	1	1	–	–	–	3
a. Stationary Combustion Sources	**3**	**1**	**1**	–	–	–	**3**
Electricity and Heat Generation	3	2	1	–	–	–	3
Fossil Fuel Industries	2	1	1	–	–	–	2
Petroleum Refining	2	1	1	–	–	–	2
Fossil Fuel Production	3	1	1	–	–	–	2
Mining	3	1	1	–	–	–	3
Manufacturing Industries	3	1	1	–	–	–	3
Iron and Steel	3	1	1	–	–	–	3
Non-Ferrous Metals	3	1	1	–	–	–	3
Chemical	3	2	1	–	–	–	3
Pulp and Paper	3	1	1	–	–	–	3
Cement	3	1	1	–	–	–	3
Other Manufacturing	3	1	1	–	–	–	3
Construction	3	1	1	–	–	–	3
Commercial & Institutional	3	1	1	–	–	–	3
Residential	3	1	1	–	–	–	2
Agriculture & Forestry	3	1	1	–	–	–	3
b. Transportation	**3**	**1**	**1**	–	–	–	**2**
Domestic Aviation	3	1	1	–	–	–	2
Road Transportation	3	2	2	–	–	–	3
Light-Duty Gasoline Vehicles	3	2	2	–	–	–	3
Light-Duty Gasoline Trucks	3	2	2	–	–	–	3
Heavy-Duty Gasoline Vehicles	3	2	2	–	–	–	3
Motorcycles	3	2	2	–	–	–	3
Light-Duty Diesel Vehicles	3	1	1	–	–	–	3
Light-Duty Diesel Trucks	3	1	1	–	–	–	3
Heavy-Duty Diesel Vehicles	3	1	1	–	–	–	3
Propane & Natural Gas Vehicles	3	1	1	–	–	–	2
Railways	3	1	1	–	–	–	1
Domestic Marine	3	1	1	–	–	–	2
Others	2	1	1	–	–	–	1
Off-Road Gasoline	1	1	1	–	–	–	1
Off-Road Diesel	2	1	1	–	–	–	1
Pipelines	3	2	1	–	–	–	3
c. Fugitive Sources	**2**	**2**	–	–	–	–	**3**
Coal Mining	–	1	–	–	–	–	1
Oil and Natural Gas	2	2	–	–	–	–	3
Oil	3	2	–	–	–	–	2
Natural Gas	2	2	–	–	–	–	2
Venting	2	–	–	–	–	–	2
Flaring	3	3	–	–	–	–	2
INDUSTRIAL PROCESSES	3	–	3	2	3	3	3
a. Mineral Production	**2**	–	–	–	–	–	**2**
Cement	2	–	–	–	–	–	2
Lime	1	–	–	–	–	–	1
Limestone and Soda Ash Use	2	–	–	–	–	–	2
b. Chemical Industry	**2**	–	**3**	–	–	–	**2**
Ammonia Production	2	–	–	–	–	–	2
Nitric Acid Production	–	–	2	–	–	–	2
Adipic Acid Production	–	–	3	–	–	–	3
c. Metal Production	**2**	–	–	–	**3**	**3**	**3**
Iron and Steel Production	3	–	–	–	–	–	3
Aluminium Production	2	–	–	–	3	–	3
SF_6 Used in Magnesium Smelters and Casters	–	–	–	–	–	3	3
d. Consumption of Halocarbons and SF_6	–	–	–	**2**	**2**	**2**	**2**
e. Other & Undifferentiated Production	**2**	–	–	–	–	–	**2**
SOLVENT & OTHER PRODUCT USE	–	–	2	–	–	–	2
AGRICULTURE	–	3	2	–	–	–	2
a. Enteric Fermentation	–	**3**	–	–	–	–	**3**
b. Manure Management	–	**2**	**2**	–	–	–	**2**
c. Agricultural Soils	–	–	**2**	–	–	–	**2**
Direct Sources	–	–	2	–	–	–	2
Indirect Sources	–	–	1	–	–	–	1
WASTE	2	2	1	–	–	–	2
a. Solid Waste Disposal on Land	–	**2**	–	–	–	–	**2**
b. Wastewater Handling	–	**2**	**1**	–	–	–	**2**
c. Waste Incineration	**2**	**1**	**1**	–	–	–	**2**
LAND USE, LAND-USE CHANGE AND FORESTRY	2	2	2	–	–	–	2
a. Forest Land	**2**	**2**	**2**	–	–	–	**2**
b. Cropland	**2**	–	–	–	–	–	**2**
c. Grassland	**1**	–	–	–	–	–	**1**
d. Wetlands	–	–	–	–	–	–	–
e. Settlements	**1**	–	–	–	–	–	**1**

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ANNEX 15: OZONE AND AEROSOL PRECURSORS

National summary tables for SO_x, NO_x, CO, and NMVOCs are included in this annex. These gases are reported to the United Nations Economic Commission for Europe (UNECE) by the Criteria Air Contaminants (CAC) Division at Environment Canada under the Convention on Long-range Transboundary Air Pollution. As recommended by the Conference of Parties to the UNFCCC (FCCC/SBSTA/2004/8), Annex 1 Parties should provide information on indirect GHGs such as CO, NO_x, MNVOCs, and SO_x in the NIR.

These gases do not have a direct global warming effect, but either influence the creation and destruction of tropospheric and stratospheric ozone or affect the terrestrial radiation absorption, as in the case of SO_x. These gases can impact the climate by acting as short-lived GHGs, alter atmospheric lifetimes of other GHGs, and form GHGs, as in the case of CO reacting with hydroxyl radical to form CO_2 in the atmosphere. These emissions are produced by a number of sources, which include fossil fuel combustion in the energy and transportation sectors, industrial production, biomass combustion, etc.

TABLE A15-1: Carbon Monoxide Emissions Summary for Canada

	Carbon Monoxide													
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
CRF Sector Categories	kt CO													
National Total	**15 451**	**14 362**	**14 357**	**13 489**	**13 508**	**13 595**	**12 605**	**12 154**	**11 836**	**11 342**	**10 589**	**10 359**	**10 152**	**10 140**
1 A 1 a Public Electricity and Heat Production	65	68	65	24	25	24	25	24	24	25	28	29	30	32
1 A 1 b Petroleum Refining	13	13	13	19	19	18	18	19	19	19	17	17	16	16
1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	42	40	42	47	53	57	59	66	69	71	73	73	70	68
1 A 2 Manufacturing Industries and Construction	658	629	687	1 014	910	933	947	946	894	930	688	691	685	694
1 A 3 a ii (i) Civil Aviation (Domestic, LTO)	63	58	54	52	54	55	53	55	60	59	57	58	58	60
1 A 3 a ii (ii) Civil Aviation (Domestic, Cruise)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 3 b Road Transportation	9 800	9 307	9 143	8 323	8 422	7 830	7 446	7 023	6 729	6 193	5 729	5 473	5 197	5 053
1 A 3 c Railways	22	22	21	21	23	23	22	23	22	20	21	21	22	20
1 A 3 d ii National Navigation	8	8	8	7	8	8	7	7	7	7	14	14	14	14
1 A 3 e Other	2 302	2 348	2 393	2 439	2 484	2 528	2 530	2 511	2 522	2 531	2 554	2 558	2 601	2 653
1 A 4 a Commercial/Institutional	5	5	5	6	6	6	6	6	6	6	8	10	11	11
1 A 4 b Residential	1 041	650	645	619	637	632	623	626	626	623	676	657	679	687
1 A 4 c Agriculture/Forestry/Fishing	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 5 a Other, Stationary (Including Military)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 5 b Other, Mobile (Including Military)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 B 1 Fugitive Emissions from Solid Fuels	4	4	4	1	1	1	1	1	1	1	2	2	2	2
1 B 2 Oil and Natural Gas	19	19	20	12	13	13	13	14	15	15	53	61	71	84
2 A Mineral Products[1]	5	5	5	37	23	25	27	24	30	27	14	14	14	14
2 B Chemical Industry	16	16	16	21	21	21	21	21	21	21	19	20	22	23
2 C Metal Production	335	296	292	323	292	313	294	312	310	299	277	299	307	354
2 D Other Production[1]	66	75	74	132	131	123	126	126	125	129	116	115	102	99
2 G Other	11	11	11	13	14	12	13	13	13	13	18	16	16	16
3 A Paint Application	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 B Degreasing and Dry Cleaning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 C Chemical Products, Manufacture and Processing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 D Other (Including Products Containing HMs and POPs)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 B Manure Management[2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 C Rice Cultivation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 D 1 Direct Soil Emission	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4 F Field Burning of Agricultural Wastes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 G Other[3]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 B Forest and Grassland Conversion	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 A Solid Waste Disposal on Land	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	1
6 B Wastewater Handling	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N//A	N/A	N/A	N/A	N/A	N/A
6 C Waste Incineration[4]	10	10	9	6	5	5	5	5	5	5	6	7	7	7
6 D Other Waste[5]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7 Other	965	779	849	372	367	967	368	329	339	347	220	224	229	233

Notes:

1 Including product handling.

2 Including ammonia from enteric fermentation.

3 Including particulate matter sources.

4 Excludes waste incineration for energy (this is included in 1 A 1).

5 Includes accidental fires.

N/A = not applicable;

IE = included elsewhere;

LTO = landing and takeoff;

HMs = heavy metals;

POPs = persistent organic pollutants.

Totals may not add due to rounding.

TABLE A15-2: Nitrogen Oxides Emissions Summary for Canada

CRF Sector Categories	Nitrogen Oxides 1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	kt NO_2													
National Total	**2759**	**2685**	**2650**	**2561**	**2601**	**2608**	**2557**	**2587**	**2620**	**2571**	**2583**	**2578**	**2569**	**2559**
1 A 1 a Public Electricity and Heat Production	249	256	245	248	250	242	252	247	251	253	283	280	281	288
1 A 1 b Petroleum Refining	27	26	26	23	22	23	22	22	22	22	24	23	22	22
1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	152	147	156	175	199	210	219	250	252	264	277	286	295	305
1 A 2 Manufacturing Industries and Construction	163	170	168	131	133	140	128	131	130		112	110	115	117
1 A 3 a ii (i) Civil Aviation (Domestic, LTO)	72	61	57	56	55	60	63	64	73	65	58	59	58	59
1 A 3 a ii (ii) Civil Aviation (Domestic, Cruise)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 3 b Road Transportation	1212	1139	1107	1052	1036	1006	968	949	972	922	850	831	794	753
1 A 3 c Railways	114	115	112	111	118	118	114	122	114	107	109	118	120	117
1 A 3 d ii National Navigation	99	93	92	85	90	90	82	81	82	78	111	110	111	112
1 A 3 e Other	368	377	385	393	401	409	415	419	421	422	425	420	417	413
1 A 4 a Commercial/Institutional	24	24	24	29	30	29	29	29	29	29	31	32	33	38
1 A 4 b Residential	49	46	46	45	47	46	45	46	46	45	47	46	46	46
1 A 4 c Agriculture/Forestry/Fishing	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 5 a Other, Stationary (Including Military)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 5 b Other, Mobile (Including Military)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 B 1 Fugitive Emissions from Solid Fuels	16	16	15	17	17	16	17	16	17	17	17	17	17	17
1 B 2 Oil and Natural Gas	59	57	60	64	69	71	73	80	80	83	114	122	132	143
2 A Mineral Products[1]	29	27	28	34	34	35	33	33	36	33	33	33	33	35
2 B Chemical Industry	24	26	27	27	28	28	24	26	25	25	29	29	29	29
2 C Metal Production	38	40	38	18	18	18	18	18	18	19	13	12	13	14
2 D Other Production[1]	30	32	32	29	29	30	28	28	28	28	27	26	27	27
2 G Other	17	18	17	15	16	16	15	15	15	15	11	11	11	11
3 A Paint Application	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 B Degreasing and Dry Cleaning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 C Chemical Products, Manufacture and Processing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 D Other (Including Products Containing HMs and POPs)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 B Manure Management[2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 C Rice Cultivation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 D 1 Direct Soil Emission	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4 F Field Burning of Agricultural Wastes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 G Other[3]	0	0	0	1	1	0	1	1	1	1	0	0	0	0
5 B Forest and Grassland Conversion	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 A Solid Waste Disposal on Land	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6 B Wastewater Handling	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6 C Waste Incineration[4]	2	3	2	3	3	3	3	3	3	3	6	6	6	6
6 D Other Waste[5]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7 Other	15	12	13	8	8	17	8	8	8	8	6	6	6	6

Notes:

1 Including product handling.

2 Including ammonia from enteric fermentation.

3 Including particulate matter sources.

4 Excludes waste incineration for energy (this is included in 1 A 1).

5 Includes accidental fires.

N/A = not applicable;

IE = included elsewhere;

LTO = landing and takeoff;

HMs = heavy metals;

POPs = persistent organic pollutants.

Totals may not add due to rounding.

TABLE A15-3: Non-Methane Volatile Organic Compounds Emissions Summary for Canada

	Volatile Organic Compounds (Non-Methane)													
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
CRF Sector Categories	kt NMVOC													
National Total	**3093**	**2848**	**2844**	**2545**	**2589**	**2729**	**2555**	**2513**	**2510**	**2449**	**2666**	**2670**	**2684**	**2705**
1 A 1 a Public Electricity and Heat Production	2	2	2	3	3	3	3	3	3	3	2	2	3	3
1 A 1 b Petroleum Refining	6	6	6	3	3	3	3	3	3	3	2	2	2	2
1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	19	20	21	22	23	24	26	26	27	25	26	27	27	28
1 A 2 Manufacturing Industries and Construction	76	71	76	75	74	73	73	73	71	74	61	61	59	59
1 A 3 a ii (i) Civil Aviation (Domestic, LTO)	10	9	9	9	9	10	10	10	11	11	10	10	10	10
1 A 3 a ii (ii) Civil Aviation (Domestic, Cruise)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 3 b Road Transportation	756	702	680	602	607	557	523	482	459	441	405	379	351	328
1 A 3 c Railways	6	6	6	6	6	6	6	6	6	5	5	5	6	5
1 A 3 d ii National Navigation	13	12	12	11	12	12	11	11	11	11	9	9	9	9
1 A 3 e Other	301	305	309	313	317	321	314	303	299	297	298	292	288	285
1 A 4 a Commercial/Institutional	0	0	0	0	0	0	0	0	0	0	1	13	13	13
1 A 4 b Residential	347	145	144	137	140	139	137	138	138	138	150	94	96	97
1 A 4 c Agriculture/Forestry/Fishing	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 5 a Other, Stationary (Including Military)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 5 b Other, Mobile (Including Military)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 B 1 Fugitive Emissions from Solid Fuels	2	2	1	2	2	2	2	2	2	2	1	1	1	1
1 B 2 Oil and Natural Gas	696	708	741	749	768	797	841	840	868	833	865	919	948	979
2 A Mineral Products[1]	5	5	4	4	4	3	4	4	4	4	2	2	1	1
2 B Chemical Industry	31	31	30	23	23	22	22	22	22	22	11	12	13	15
2 C Metal Production	2	2	2	3	3	4	3	3	3	3	5	5	4	5
2 D Other Production[1]	67	69	69	71	71	73	70	72	71	71	75	73	72	73
2 G Other	58	57	56	61	63	60	62	61	61	61	73	140	146	147
3 A Paint Application	162	166	160	132	130	139	121	130	127	123	111	104	105	107
3 B Degreasing and Dry Cleaning	306.21	319.15	316.07	273.74	285.03	250.36	277.94	279.04	279.09	277.73	310.29	295.47	300.7	305.13
3 C Chemical Products, Manufacture and Processing	1.23	1.23	1.26	2.09	2.15	2.09	2.13	2.11	2.12	2.12	2.56	2.46	2.53	2.59
3 D Other (Including Products Containing HMs and POPs)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 B Manure Management[2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 C Rice Cultivation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 D 1 Direct Soil Emission	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 F Field Burning of Agricultural Wastes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 G Other[3]	174	165	150	14	13	174	15	13	13	13	215	198	201	205
5 B Forest and Grassland Conversion	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 A Solid Waste Disposal on Land	7	5	5	5	5	7	5	5	5	5	9	7	7	7
6 B Wastewater Handling	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 C Waste Incineration[4]	2	2	2	2	2	2	2	2	2	2	2	2	2	2
6 D Other Waste[5]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 Other	45	37	40	23	23	46	23	21	22	22	15	15	16	16

Notes:

1 Including product handling.

2 Including ammonia from enteric fermentation.

3 Including particulate matter sources.

4 Excludes waste incineration for energy (this is included in 1 A 1).

5 Includes accidental fires.

N/A = not applicable;

IE = included elsewhere;

LTO = landing and takeoff;

HMs = heavy metals;

POPs = persistent organic pollutants.

Totals may not add due to rounding.

TABLE A15-4: Sulphur Oxides Emissions Summary for Canada

	Sulphur Oxides													
CRF Sector Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	kt SO_2													
National Total	**3230**	**3580**	**3086**	**2436**	**2397**	**2512**	**2429**	**2457**	**2466**	**2448**	**2352**	**2387**	**2343**	**2390**
1 A 1 a Public Electricity and Heat Production	679	692	666	539	536	523	538	527	540	546	625	614	606	613
1 A 1 b Petroleum Refining	105	109	110	137	126	120	120	124	122	124	101	102	101	102
1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	137	132	139	153	172	181	188	210	206	211	223	222	220	218
1 A 2 Manufacturing Industries and Construction	268	284	284	204	210	205	228	220	209	213	133	136	133	139
1 A 3 a ii (i) Civil Aviation (Domestic, LTO)	4	4	3	3	3	4	4	4	4	4	4	4	4	4
1 A 3 a ii (ii) Civil Aviation (Domestic, Cruise)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 3 b Road Transportation	71	74	72	76	65	42	41	35	27	26	25	25	17	17
1 A 3 c Railways	5	5	5	5	5	5	5	6	5	5	4	5	5	5
1 A 3 d ii National Navigation	36	33	33	33	33	33	29	28	27	29	33	32	32	32
1 A 3 e Other	24	23	19	25	25	13	14	17	18	18	17	19	18	18
1 A 4 a Commercial/Institutional	19	19	20	13	13	14	13	13	13	13	21	22	23	39
1 A 4 b Residential	33	33	33	18	19	19	18	19	19	18	16	16	15	15
1 A 4 c Agriculture/Forestry/Fishing	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 5 a Other, Stationary (Including Military)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 A 5 b Other, Mobile (Including Military)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1 B 1 Fugitive Emissions from Solid Fuels	21	21	19	18	18	18	18	17	17	18	17	16	16	16
1 B 2 Oil and Natural Gas	253	252	264	285	291	295	295	308	308	307	245	249	253	257
2 A Mineral Products[1]	39	40	37	30	32	33	29	31	31	31	31	32	29	31
2 B Chemical Industry	4	4	5	4	4	5	3	3	3	3	5	6	5	7
2 C Metal Production	1 475	1 793	1 317	855	806	969	842	857	877	844	823	860	839	847
2 D Other Production[1]	32	36	36	18	19	18	18	18	18	18	17	18	17	18
2 G Other	16	16	16	12	12	12	12	12	12	12	8	8	7	7
3 A Paint Application	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 B Degreasing and Dry Cleaning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 C Chemical Products, Manufacture and Processing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 D Other (Including Products Containing HMs and POPs)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 B Manure Management[2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 C Rice Cultivation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 D 1 Direct Soil Emission	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 F Field Burning of Agricultural Wastes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 G Other[3]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 B Forest and Grassland Conversion	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 A Solid Waste Disposal on Land	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6 B Wastewater Handling	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6 C Waste Incineration[4]	2	2	2	1	1	1	1	1	1	1	2	2	2	2
6 D Other Waste[5]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 Other	6	7	7	4	6	5	11	9	6	6	1	1	2	2

Notes:

1 Including product handling.

2 Including ammonia from enteric fermentation.

3 Including particulate matter sources.

4 Excludes waste incineration for energy (this is included in 1 A 1).

5 Includes accidental fires.

N/A = not applicable;

IE = included elsewhere;

LTO = landing and takeoff;

HMs = heavy metals;

POPs = persistent organic pollutants.

Totals may not add due to rounding.

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